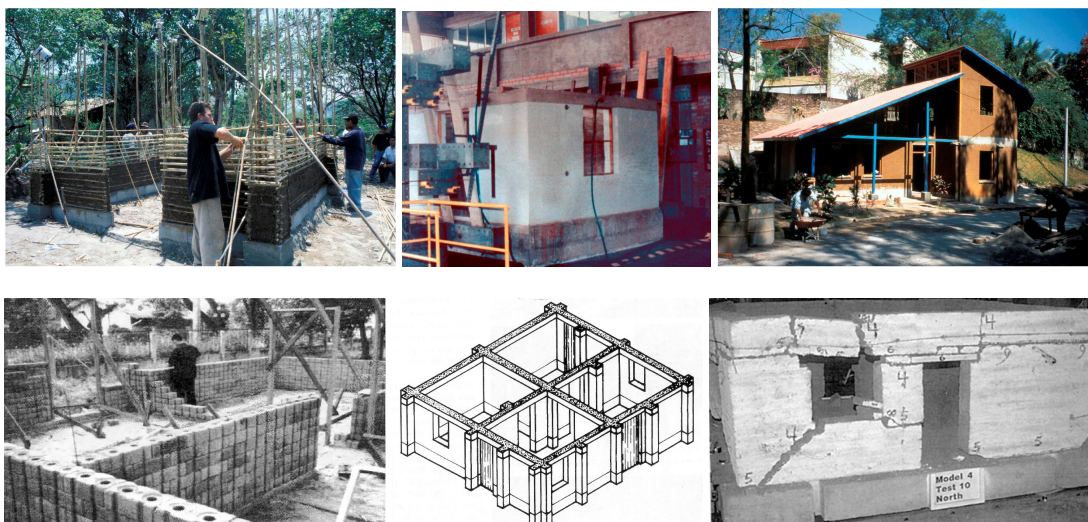
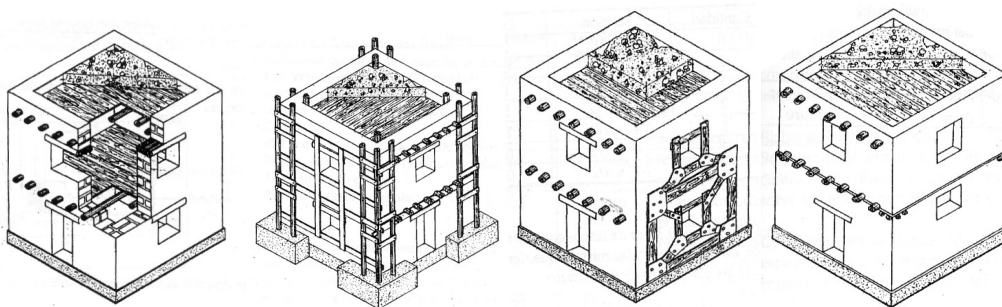


Earthquake resistant earthen construction

Reference bibliography



CRATerre-EAG

Authors

Wilfredo Carazas-Aedo, Matthieu Dupont de Dinechin
David Gandreau, Hubert Guillaud, Majid Hajmirbaba
with a contribution of Fred Webster

Scientific supervision

Hubert Guillaud and Philippe Garnier
With Hugo Houben and Thierry Joffroy



CRATerre-EAG

Novembre 2004

SUMMARY

PART 1 :

Introduction and brief presentation

..... p. 1

PART 2 :

**Earthen Construction and seismic risk:
a scientific review (ppt presentation)**

..... p. 7

PART 3 :

**Earthquake resistant earthen architecture
Bibliography of reference**

..... p. 27

Earthquake resistant earthen construction

Bibliography of reference

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PART 1: Introduction and brief presentation

(by Arch.Hubert Guillaud, as scientific supervisor)

Enlarging the access to the scientific literature

The following bibliography covering the field of earthquake resistant earthen architecture has been elaborated within the frame of the “Bam conservation and reconstruction project” which is supported by the Ministry of Culture and Communication of France. The objective of this work is to establish an updated base for a bibliography of reference that has not been undertaken within this specific field yet. Even if partial approaches to this objective have been achieved by various authors who have given important scientific contributions - mainly within international manifestations (seminars, colloquia or congresses) – it is not misused saying that such an essential scientific document, and tool, has not been fulfilled up to now. Thus, the present bibliography of reference certainly passes through a new step in this direction and will certainly facilitate the access to the available scientific literature for a wider population of researchers and professionals who are concerned by activities in the field. We also know that much more has to be done in order to propose a very efficient tool. For instance, the on line presentation of this bibliography would be a new phase of development that would undoubtedly be appreciated by the international scientific and the professional community and we hope that this further step will be achieved as soon as possible.

The methodology

The identification of the reference documents has been mainly done within the Documentation Centre of CRATerre-EAG and within the Library of ICCROM.

Other specific scientific works must be raised up. A recent scientific research that has been undertaken within the Project TERRA (CRATerre-EAG/ICCROM/Getty Conservation Institute), entitled “**Research in earthen architecture conservation : a literature review**” (2002), conducted by Hubert Guillaud (CRATerre-EAG) and Erica Avrami (GCI), as editors, and presenting - among a set of 8 articles ¹ written by several scientists - a specific review on the “**Seismic deterioration/pathology of earthen architecture and seismic interventions in earthen architecture**” (by F. Webster), has been undertaken, giving the most recent state of the art within the field. We are presenting a brief

¹ All contributing authors of the scientific literature review are : Claudia Cancino, Hubert Guillaud, Richard Hughes, Anne Oliver, Leslie Rainer, Brian V. Ridout, Bruce Velde and, Fred Webster.

synthesis of this work hereafter. This scientific review was including a new bibliography which has been particularly useful for updating and enlarging our bibliography of reference. The main sources of reference that are included in Fred Webster's bibliography are :

- **Terra 2000** 8th International Conference on the Study and Conservation of Earthen Architecture.²
- **Terra 93** 7th International Conference on the Study and Conservation of Earthen Architecture.³
- **Adobe 90** 6th International Conference of Earthen Architecture.⁴
- **IWEBSA** International Workshop on Earthen Buildings in Seismic Areas.⁵
- **12WCEE** 12th World Conference on Earthquake Engineering.⁶
- **11WCEE** 11th World Conference on Earthquake Engineering.⁷
- **10WCEE** 10th World Conference on Earthquake Engineering.⁸
- **9WCEE** 9th World Conference on Earthquake Engineering.⁹
- **8WCEE** 8th World Conference on Earthquake Engineering.⁹
- **7WCEE** 7th World Conference on Earthquake Engineering.⁹
- **GSAP** Report of First Year Activities.
- **NISEE** National Information Service for Earthquake Engineering
- **Earthquake Spectra** Journal of the Earthquake Engineering Research Institute.¹⁰

The work that has been done by the authors of this new bibliography, has allowed to identify close to 300 documents among which 150 has been considered to be worthy part of this final document. The selection criteria of the sources has focused on the specific problematics of the earthen architecture and its resistance to the seismic risk, conducting the authors to put aside several articles which were more concerned by the general and more common seismic structural engineering, or various papers or written material being part of a wider dissemination of information without enough scientific value.

The final selection of the bibliographical sources has been done according 5 main themes which are the following:

- T1 : Seismic behaviour of earthen architectures;
- T2 : Seismic resistant building cultures ;
- T3 : Recommendations and standards for seismic resistant earthen architecture ;
- T4 : After seism retrofitting of earthen architectures;
- T5 : Bam earthquake.

General comments

Quite numerous publications covering the investigated field are existing. Since this terrible problem of seismic risk to which many people of the world is exposed has been much more considered, there is an important effort of continuous research activity that has been developed throughout the world during the past 50 years. This effort has been particularly driven in countries where an earthen building tradition is existing for centuries which are dramatically exposed to the seismic risk. A lot of

² Preprints of the 8th International Conference on the Study and Conservation of Earthen Architecture, May 2000, Torquay, England.

³ Proceedings of the 7th International Conference on the Study and Conservation of Earthen Architecture, October 1993, Silves, Portugal.

⁴ Preprints of the 6th International Conference of Earthen Architecture, October 1990, Las Cruces, NM.

⁵ Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, May 24-28, 1981 / Washington: National science foundation

⁶ Proceedings of the twelfth world conference on earthquake engineering, New Zealand society for earthquake engineering, Upper Hutt, New Zealand, 2000

⁷ Proceedings of the tenth world conference on earthquake engineering, Balkema, Rotterdam, Netherlands, 1992

⁸ proceedings of the ninth world conference on earthquake engineering, Tokyo/Kyoto, Japan, August 1988

⁹ Proceedings of the seventh world conference on earthquake engineering, Istanbul, Turkey, 1980

¹⁰ Volume 1, novembre 1984 à Volume 16, November 2000

experiments has been undertaken, directed at designing and disseminating seismic resistant devices or building solutions that could be applied to the earthen construction. This scientific effort has been undertaken since the first specialised seismic engineering institutes have been created - as with the EERI settled in the year 1949¹¹ -, and with the development of the first scientific research programmes among which we can quote the UNI-CET¹² program of the Catholic University of Peru¹³, or the GSAP program of the Getty Conservation Institute¹⁴. This effort has been developed up to near times with the recent editing of standards for seismic resistant earthen constructions, after the dramatic earthquake of Gujarat, India.

The great variety of origin of the identified literature shows that a large spectrum of publications is accessible. This set covers fundamental scientific research, experimental programmes, illustrated manuals or technical guides, films and videos for self help builders as well. Among the scientific investigations, we can quote two main items of documents:

- Results of analysis that have been done on building materials, and on structures. They are mainly focusing on measurements of the constraints exerted on small scale building erected on seismic tables.
- Other experiments that have been undertaken at larger scale by researchers, architects or builders. Many times these activities have contributed to experiment ingenious seismic resistant building solutions but most of the time they are not supported by adequate financial support allowing to develop scientific measurements. Thus, the approach is much more empirical.

Considering this twin type of investigations, we can present the following general comments:

- For the improvement of the modest, or low-cost earthen social housing, we can clearly note that a usual set of building solutions is proposed which includes devices such as buttresses, vertical and horizontal reinforcements (in bamboo, wood, iron bars) embedded within the thickness of the walls, ring beams (in wood or in reinforced concrete), the reinforcement of the building materials with natural or artificial fibbers (straw, fabric, iron mesh), the improvement of the production process of the materials and of the building process with a better quality control. These solutions are well known and now experimented for sometimes.
- There are several researches and essays that have been undertaken on solutions aiming at facilitating their people's access. These are including the facilitating of the building process or the cost lowering. But, these solutions are not feasible as soon as they have to be implemented at large scale.
- Other "hyper technological" solutions are existing which are not adapted for the earthen construction, as for extra cost reasons or because of their inadaptability (shape memory alloy devices, for instance).

Among the first conclusions we can raise here a set of points:

- The scientific data are numerous. Several advanced research programmes have been developed. They result in reliable technical recommendations despite the limits of the tests which are undertaken on seismic shaking tables.
- Much more efforts has to be developed in scientific investigations as well as in the application of the resulting recommendations. There is still not enough standards and quality control in the field.

¹¹[http:// www.eeri.org](http://www.eeri.org)

¹²This program was undertaken between 1988 and 1993, jointly conducted by the *Universidad Catolica de Ingenieria*, Peru – the *Centro peruano- japonés de investigaciones Sísmicas y Mitigación de Desastres*, Peru – and the *Instituto de Ciencias de la Construcción Eduardo Torroja*, Spain

¹³ This program was undertaken between 1970 and 1985. It resulted in the publication of the Peruvian seismic resistant adobe construction standard or *Norma Adobe E-80*.

¹⁴ Getty Seismic Adobe Project, since 1990.

- The social and economical data are not so much considered. An effort in this direction would help reaching more realistic results and would warrant a better applicability of laboratory research results.
- There is not a systematic approach for investigating or studying on the traditional seismic resistant building cultures.
- Field experiments are really interesting and they put in light ingenious technical solutions as well as data on their application feasibility within their cultural and social contexts testifying of their level of appropriation by the local populations.

Actual state of the art in seismic resistant earthen construction

(By Fred Webster, 2000; synthesized by Arch. Hubert Guillaud for the Terra 2003 International conference that was held in Yazd, Iran, in November 2003).

Fred Webster has noted the existence of three main categories of research related to seismic deterioration / pathology and seismic intervention in earthen architecture. They are: 1) field observations; 2) testing; and, 3) analytical. These categories embed distinct subcategories which are:

A) Field observations:

- Damage patterns of URMs (Unreinforced Masonry);
- Performance of strengthened URMs;
- Performance based on "seismic culture".

B) Testing:

- Study of building parameters in relation to performance;
- Specific seismic intervention development.

C) Analytical:

- Damage / collapse patterns of URMs;
- Specific seismic intervention development;
- Predicting performance.

The literature which has been covered by the review includes as main sources the proceedings of the recent International Conferences on the Study and Conservation of Earthen Architecture (Adobe 90, Terra 93, and Terra 2000), proceedings of successive World Conferences on Earthquake engineering (7 to 12th WCEE), and other reports covering the topic (GSAP, NISEE, IWEBSA, EESD, SMiRT, MSJ and Middle East and Mediterranean Conference on Earthen and Low-Strength Masonry Buildings in Seismic Areas).

Field Observations

Field observations of earthquake damage to earthen architecture are often part of a much larger effort to observe and record damage to all sorts of man-made structures, as well as natural geologic phenomena. Webster notes that reporting activities immediately following an earthquake vary from event to event (Holmes and Lizundia: 1990), regarding performance of URM structures), some of them giving a reasonable amount of useful information (Erdick and Gulkan: 1993), regarding the behavior of low-strength unreinforced masonry structures in and around Erzincan (Turkey, earthquake of the year 1992).

Sometimes a more extensive reconnaissance effort has been conducted on a specific type of building as historic earthen buildings (Tolles, Webster, Crosby and Kimbro: 1996). In some field observation reports, the performances of URM buildings that have been previously retrofitted are examined following an event (Deppe: 1988; Moore, Kobzeff, Diri, and Arnold: 1988). A few of the buildings are reported by Tolles, Webster, Crosby and Kimbro (1996) that has seismic interventions in place prior to

the Northridge earthquake. The observations are corroborated by in shaking table laboratory tests on model buildings (Benedetti, Carydis, and Pezzoli : 1998). There is examples where a "seismic culture" (traditional methods of construction) influences the design of the structures (Erdik and Gulkan: 1993; Arya: 2000). Tobriner (1984), provides a history of the development of reinforced masonry construction designed to resist earthquakes from 1755 to 1907. He presents a system called the *gaiola* (internal wooden cage) which was devised by engineers after the earthquake of November 1, 1755 in Portugal (Pombale's system) and a similar solution which was used in Italy in 1783, called *la casa baraccata*. Iron hoop reinforcing was discovered in England in 1825 for reinforcing brick walls. Such a device was widespread used in Italy after strong tremblors in 1854. Beyond experiments of iron bars reinforcing in cement mortar for brick masonry, after the severe earthquakes in 1865 and 1868 in San Francisco, earthquake-resistant masonry construction only came of age after the lessons of the 1906 earthquake were repeated in the Santa Barbara earthquake of 1925 and the Long Beach earthquake of 1933.

Testing

Testing in the laboratory wall specimens and scale models of buildings is an effective means of developing innovative seismic interventions, as well as a means of studying the behavior and damage patterns of unreinforced buildings. On this purpose, see Gulkan and Gurdil (1988) regarding an experimental study of the behavior of square adobe wall panels subjected to a constant in-plane compression normal to the horizontal mortar joints and an incrementally applied diagonal load for compressive and shear forces. Refer also to Vargas-Neumann (1993) who presented a testing program carried out on rammed earth construction at the Catholic University of Peru, which addresses both the study of building parameters in relation to performance and specific seismic intervention development.

Other research programs have developed a great deal of understanding regarding the behavior of earthen structures during earthquakes as well as the means of mitigating the sever consequences of the damages to them. Here F. Webster refers to Meli, Hernandez, and Padilla: 1981; to Vargas, Bariola, Blondet, and Lehta: 1983; and to Ottazzi, Yep, Blondet, Villa-Garcia, and Ginocchio: 1988. These experiments report the testing on models of reinforced concrete or wood bond beam at the top of the walls, of welded wire mesh nailed to both faces of the walls, and of the use of steel rods tying both faces in the upper part of the walls. As a brief conclusion, the use of the wire mesh is considered the most efficient method of reinforcing the existing adobes.

At the Catholic University of Peru, Vargas, Bariola, Blondet, and Mehta (1983) first studied the factors that influence the strength of adobe masonry, including 1) material properties of the soil used; 2) Drying process(shrinkage); 3) effect of additive such as lime, cement, and a dispersing agent such as sodium carbonate; and, 4) the construction process. Later on the same university has conducted shake-table tests on eight full-scale models representing on-storey rural dwellings (Ottazzi, Yep, Blondet, Villa-Garcia, and Ginocchio: 1988). Again in Peru, Torrealva (1986) reports a retrofit study following the 1983 Popayan earthquake in Columbia.

In addition to testing programs on adobe in North and South America in the 1970s, 80s, and 90s, relevant tests were also conducted in Europe. F. Webster mentions successive researches developed in Ljubljana, Slovenia, the former Yugoslavia (Tomazevic and Zarnic: 1985; Tomazevic, Velechovsky, and Weiss: 1993; and, Tomazevic, Lutman, and Weiss: 1996). These researches tested the effect of horizontal reinforcement and mortar strength on the strength and ductility of 16 small-scale masonry wall specimens, subjecting them under constant compressive load and lateral load reversals. As a brief conclusion, it was found that the ductility of the wall could be improved by adding a sufficient amount of horizontal reinforcement. However, after a certain point, the effectiveness of the reinforcement is inversely proportional to the reinforcement ratio.

The European Commission sponsored research and testing program on stone and brick masonry, which are also relevant to earthen architecture (Benedetti, Carydis, and Pezzoli: 1998; Castellano, Indirli, Martelli, Azevedo, Sincaian, Tirelli, Renda, Croci, Biritognolo, Bonci, and Viskovic: 1999). The first team (1998) tested (at ISMES, Bergamo, Italy, and LEE, Athens, Greece) a total of 14 half-scale model 2-story brick and stone masonry buildings, some repaired and strengthened by various

interventions, and tested again in a total of 119 shake-table tests. The efficiency of various retrofitting methods was also studied. This research concluded that significant increase in lateral resistance might be obtained by simple techniques such as local sealing of cracks and application of horizontal tie rods.

Another European Commission funded project (ISTECH) focused on the development of innovative seismic mitigation techniques for restoring cultural heritage structures, primarily masonry buildings, damages by earthquakes. One of the most innovative techniques developed was a connection element based on the idea of using a super-elasticity material. Such devices known as Shape Memory Alloy Devices (SMADs) can be used to pre-stress masonry, yet avoid over-stressing owing to the Ni-Ti alloys's super-elastic force limitation, or plateau. The results, briefly summarized, were that the wall with the SMADs did not show visible damage. Then, applications of these devices have been made on the Bell Tower of the San Giorgio in Trignano Church, in San Martino, Italy, damaged by the 1996 Reggio Emilia earthquake, and on the transept tympana of the Basilica of St. Francis de Assisi, Italy, damaged in the September 1997 earthquake.

Analytical

Analytical tools have been used throughout most research and testing programs on earthen building models and components. F. Webster points out that among some of the more innovative developments are two analytical methods developed for determining the collapse patterns of stone masonry structures (Casolo, Parisi, and Petrini: 2000; Azevedo, Sincraian, and Lemos: 2000). The first team (Casolo et al.: 2000) developed simplified material models and numerical analysis to predict and evaluate out-of-plane seismic behavior of old masonry church façades under conditions of varying geometries, material strengths, post-elastic material behavior, and excitation characteristics. In many cases, seismic action on the façades appeared to divide them into rigid blocks connected by highly degraded zones, following simple and recurrent fracture patterns. The research developed by the second team (Azevedo et al.: 2000), utilized a discrete element method (DEM) analysis technique, which falls within the general classification of discontinuous analysis technique, to analyze the seismic behavior of masonry structural systems, particularly masonry structures. The method is capable of reproducing the phenomena of crack opening and joint sliding, to simulate progressive failure associated with crack propagation and large displacements/rotations between blocks. It is also capable of including reinforcing schemes, such as vertical and horizontal cables that link two different blocks. The method was used to assess the collapse patterns of different structural elements subjected to self-weight and seismic action, from simple arches and columns, and progressing to more complex structures as a bell tower and an aqueduct.

Brief conclusion

F. Webster points out that concerning seismic deterioration / pathology of earthen architecture, research recognizing the types of seismic damage and relating them to causes and ground shaking intensity (vulnerability analysis), is an important tool in developing effective means of mitigating these damages in future seismic events. Although the materials which are discussed in the literature differ from earthen materials in many respects, seismic performance is often quite similar and relevant to a better understanding of the seismic deterioration / pathology of earthen architecture. In general, research efforts related to earthen architecture are many but they may be extensively enhanced by looking to the several and varied research and testing efforts on stone and brick masonry interventions, most of which are applicable to earthen architecture as well.

PART 2 : Earthen Construction and seismic risk: a scientific review (ppt presentation)


We present hereafter the printed document of a PowerPoint presentation that has been devoted to a scientific review of earthen construction and seismic risk. This presentation has been made during the "International Seminar on Seismic-Resistant Earthen Architecture for the Reconstruction of Bam, that was held on 6th – 10th September 2004, organized by CRATerre-EAG and Iranian Cultural Heritage and Tourism Organisation (ICHTO), at the "Grands Ateliers de l'Isle d'Abeau, Villefontaine, France.



International Seminar on seismic-resistant earthen
architecture for the reconstruction of Bam

6th – 10th September 2004

Grands Ateliers de l'Isle d'Abeau, Villefontaine, France





Earthen construction and seismic risk

Scientific review

Hubert Guillaud
CRATerre-EAG

With the collaboration of
Wilfredo Carazas-Aedo, Matthieu Dupont de Dinechin
David Gandreau and Majid Hajmirbaba



Summary

- Introduction
 - Subject, issues & questions
 - Seisms and their impact on constructions (remind)
 - Seismic-resistant earthen construction, tradition and modernity
- Scientific review of the research on earthen construction and seismic risk
 - Studies, researches and recent experiments (low-cost housing)
 - Examples of recent projects (low-cost housing)
 - Bibliography of reference

Subject, issues & questions

On Earth, millions of people housing are built with mud

In numerous regions of the world, the seismic risk is a permanent threat for this people housing, and for the earthen architectural heritage.

Prevention and after seism intervention

What alternative building response for taking care of this seismic risk ?

What economical feasibility for the social housing : how to warrant the necessary people's accessibility ?

Building with earth : a cultural heritage of humanity ?

What to do for preserving the historical continuity of the earthen building cultures existing throughout the world ?

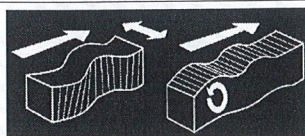
The tectonic seisms and their mechanisms

Seismic waves

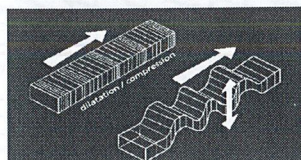
Different kind of ground waves

result in

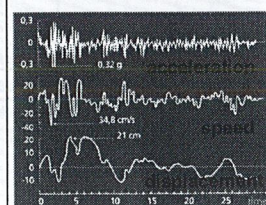
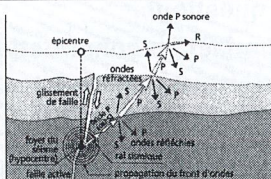
Buildings oscillations



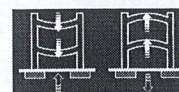
Volume waves "P" et "S"
or primary and secondary waves



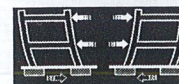
Surface waves
or Rayleigh et Love waves



A dynamic phenomenon lasting several seconds with high magnitude and intensity, renewed with aftershocks



Vertical component of extension and contraction



Horizontal component of translation

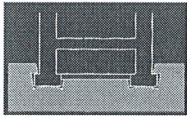
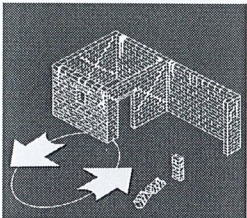


Torsions

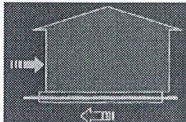
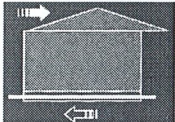
Typical effects on the buildings

Distorsion of the soil

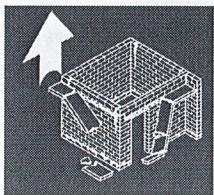
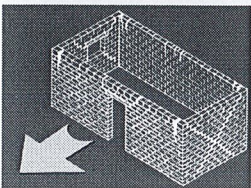
- Shortening or dilatations ("P" waves)
- Shearing ("S" waves)
- Settlement (on less dense soils)



Motion and uprising of the soil



Sliding, separation of building elements



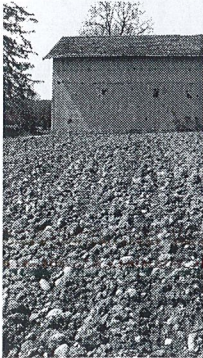
Bugling, cracking, shearing, dumping, collapsing of elements

systemic/holistic/integrated

Global approach of the seismic-resistant design

The resistance directly depends on four main factors:

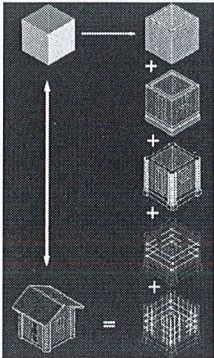
The soil / the ground
(site effects)



The building
material



The structural
design



The quality of the
building process

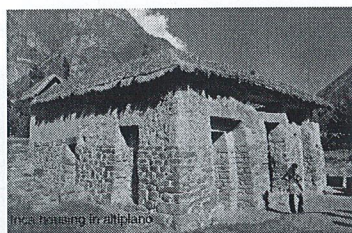


« Solid » soils are better reacting while « soft » soils are amplifying the seismic waves
Bad quality building materials, unadapted structures, deficient building processes, are increasing the effects of the seismic waves on the buildings

Examples of adobe earthquake-resistant building technologies

Between tradition and modernity

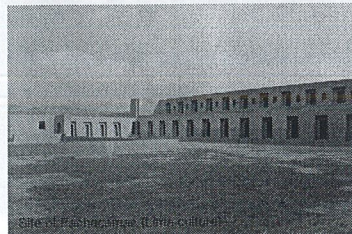
Precolombian seismic-resistant earthen building cultures The Incas of Peru



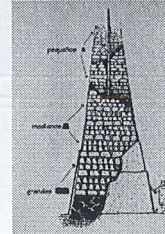
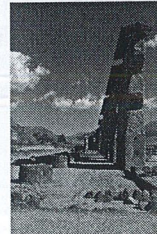
Inca housing in the Andes



Temple of Pachacamac (Inca Culture)

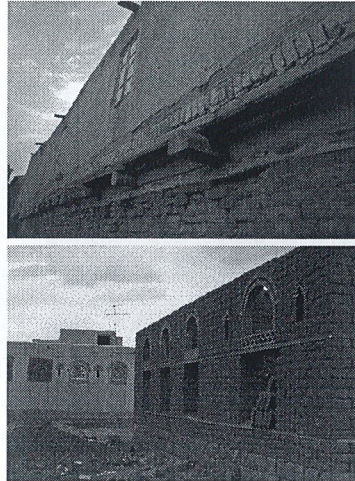
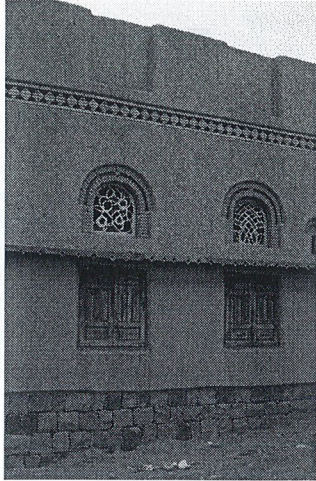


Palace of Pachacamac (Inca Culture)



The stability by the mass and the thickness of the walls; the prismatic section of the walls and a proper slenderness ratio; the vertical and horizontal reinforcement of the adobe masonry

In Uzbekistan, tradition and actuality



Wooden ring beams are cleverly positioned and flexible (ductility, horizontal motion). The position of arched bays is well-balanced and does not concentrate the voids

In Cuba

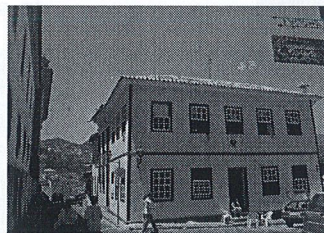


Isla Isabella (Santiago), stone, wattle and daub

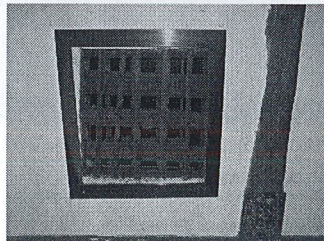


Seismic-resistant adobe housing, Holguin: embedded concrete ring-beams and buttresses

In Brazil



Ouro Preto, rammed earth, wattle and daub



Ouro Preto, detail of the structure in wattle and daub, 1st floor

The stability by the mass at the ground floor (stone or rammed earth masonry), and a flexible first floor in wooden structure infilled with wattle and daub. Other solutions with buttresses

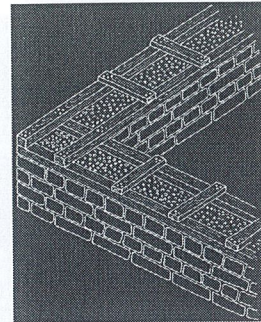
Vernacular adobe construction in Turkey



After the seism of Gediz (1970)

Successive and close horizontal wooden ring beams, vertical reinforcements, are properly positionned within the wall

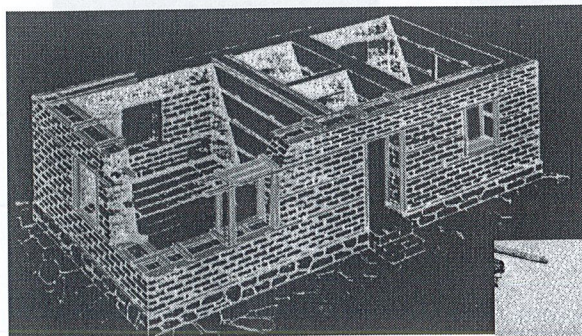
Rupture of the soil



Crossing wooden bars are connecting the two horizontal beams

In « Earthen building in seismic areas of Turkey »
BUILDING RESEARCH INSTITUTE - ALKUT AYTUN

Implementing traditional solutions in seismic areas



Irpinia - Turkey

This adobe house has
resisted to the seism of
Irpinia (1981)

Wooden ring beams are regularly
distributed within the thickness of the walls
The wooden frames of the bays are
reinforced and connected to the wooden
ring beams.

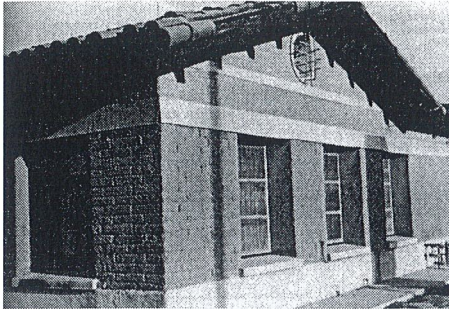


In INTERNATIONAL WORKSHOP ON EARTHEN BUILDINGS IN
SEISMIC AREAS - 1981 UNM

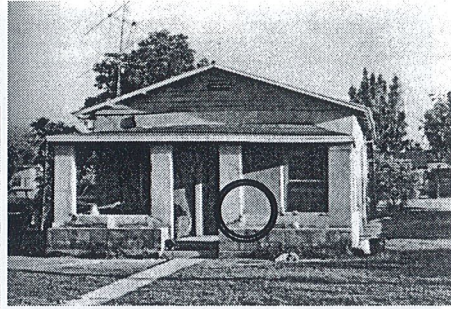
Adobe construction at the beginning of the 20th Century

United States of America

Wesmorland, California



This adobe structure has been built in 1935. Appropriate design and good maintenance



This adobe structure has been retrofitted after a seism with wooden ring beams and cables

These adobe houses have resisted to successive earthquakes that have affected California during several decades since the beginning of the 20th Century

Recent studies on building prototypes

Textile walling infilled with earth

Germany, Guatemala, 1978

- GHK-Kassel, Germany, Prof.Dr.Ing.Gernot Minke
- University Francisco Marroquin, Guatemala
- Centre Tecnologías Appropriadas, Guatemala

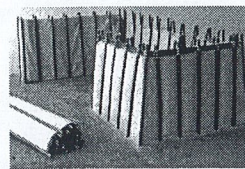
Seismic-resistant and low-cost urgent housing implementing the principle of stability by the mass



Partitions in cotton rolls infilled with earth and light aggregates (pozzolana)



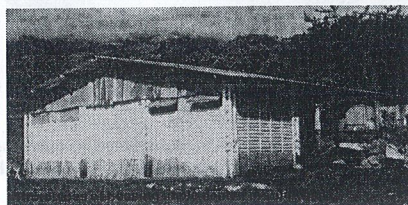
Structure in bamboo are going through the layers of cotton rolls, with wooden rings



Prefabricated elements of partition walls



Prototypes of urgent housing tested in Kassel, Germany



In « Construction Manual for earthquake resistant houses build of earth » / Gernot Minke

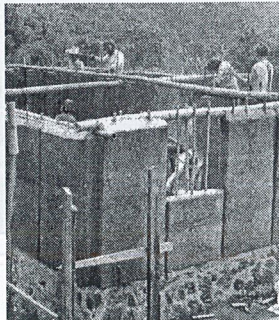
Seismic-resistant rammed-earth housing

Guatemala, 1978

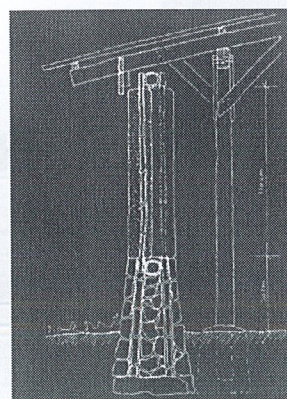
- GHK-Kassel, Germany, Prof.Dr. Ing. Gernot Minke
- University Francisco Marroquin, Guatemala
- Centro de Tecnologías Appropriadas, Guatemala



Building elements in rammed earth, stables and 80 cm thick, with integrated buttresses



These elements in rammed earth are independent
Vertical reinforcements are made of bamboo sticks that are connected by wooden ring beams



Roofing is independent from the walls

In « Construction Manual for earthquake resistant houses build of earth » / Gernot Minke
GHK - Kassel - Germany

Wattle and daub improved housing

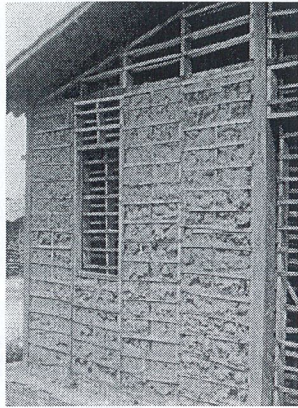
CEPED, Camari, Brazil

Brazil and Chile, 1998

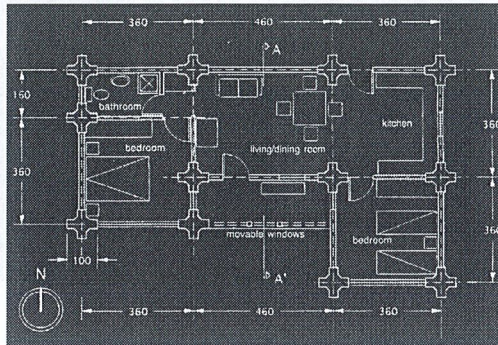
Flexible wooden structure infilled with earth (wattled and daub)

Light structure, flexible and ductile

Only the infilling must be repaired after a seism



Walling in prefabricated elements
(fast building process)



Rammed earth pillars are supporting the roof. In between these pillars partition walls are in wooden frames infilled with daub (earth and straw)

Kühn, Poblete and Trebilcock, Santiago de Chile, 1998

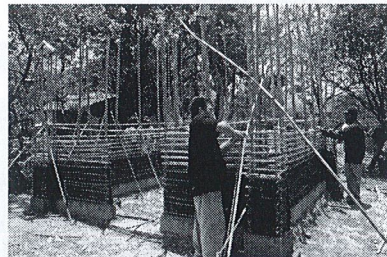
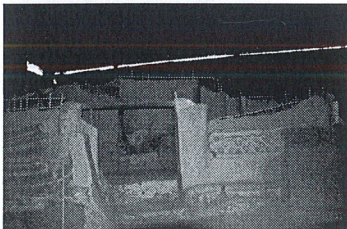
Joya de Cerén Project

Salvador, 1995

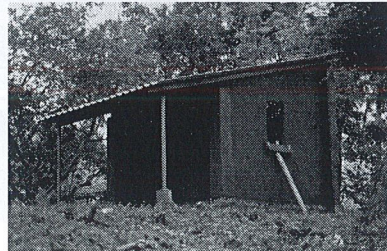
- Misereor, Germany
- Fundasal, Salvador
- CRATerre-EAG, France

Flexible vegetal structure
Buttresses at the angles
Light roofing

This project has been based on observations made at the archaeological site of Joya de Cerén testifying of an ancient seismic-resistant building culture



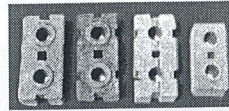
Prototype of demonstration



Arch Wilfredo Carazas Aedo, CRATerre-EAG

Interlocking CEB blocks houses

*Asian Institute of Technology,
Bangkok, 1984*



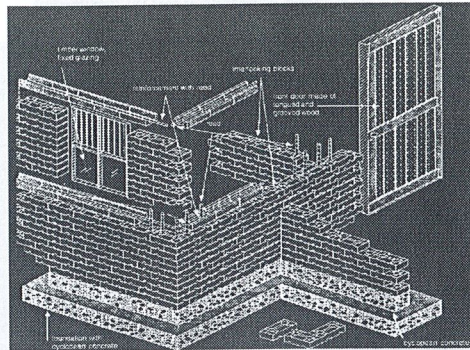
Weinhuber 1995

Prototype house in Thailand

- Efficient vertical reinforcement, easy to implement
- The grooves and tongues improve the seismic resistance

Thailande, 1984 and Venezuela, 1995

Universidad de los Andes, Caracas, 1995



Pereira 1995

- Blocks are laid without mortar (dry masonry) improving the wall flexibility



GHK, Kassel, 2001

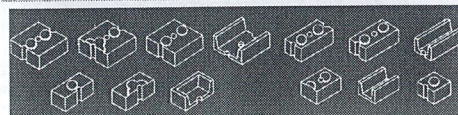
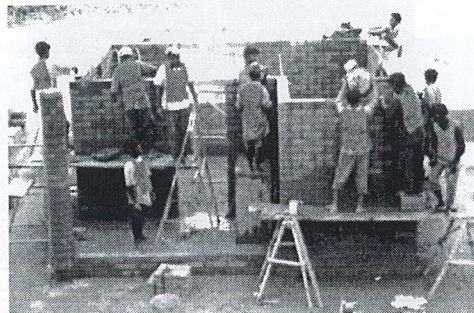
Cost effective and disaster-resistant house for the reconstruction after the seism of Gujarat, India

*Auroville Building Centre, India
Arch. Serge Maini, CRATerre-EAG*

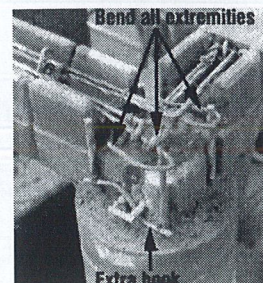
Auroville, India, 2000



Fast building organisation

Vertical and horizontal reinforcements tightly anchored



Wide range of CEB interlocking blocks





Scientific research programmes and experiments

Peru and U.S.A.



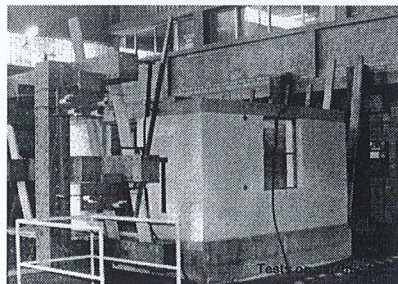
Adobe Research Programme

Lima, Peru, 1970-1985

Universidad Pontifica, Peru

- Research and tests on technical solutions to be used in governmental building projects.
- Writing of a Building Standard on earthquake resistant adobe construction

•“Norma Adobe E-080”



UNI - CET Research Programme

-Universidad Catolica de Ingenieria, Peru

-Centro peruano-japones de investigaciones
Sismicas y Mitigacion de Desastres, Peru

-Instituto de Ciencias de la Construccion Eduardo
Torroja, Spain

Peru & Spain, 1988-1993

System CET (Components of earthen structures),
rammed earth, and wattle and daub)

Modular and adaptable building system for low-
cost and seismic-resistant constructions

Ground floor: independent and self stable rammed earth
elements

First floor: wooden structure infilled with earth (wattle
and daub)

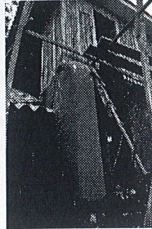
Semi-diaphragm floors



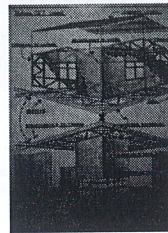
Tests on seismic table



Prototype



CET house



Manuals of design and construction for the use of CET system



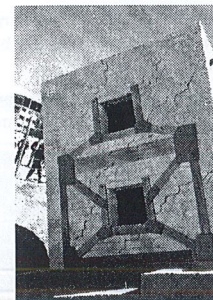
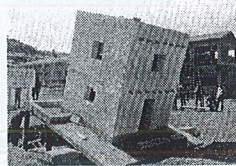
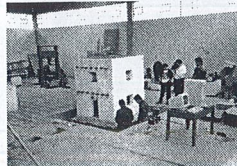
Research programme on the construction of low-cost adobe seismic-resistant housing

- Universidad de San Antonio del Abad del Cusco, Pérou
- Delft University of Technology, Pays-Bas

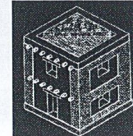
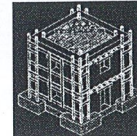
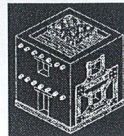
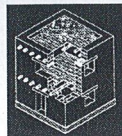
Cusco, Peru

Research and analysis on :

- Alternatives of reinforced technologies
- Retrofitting interventions on existing housing



Several prototypes have been designed and tested

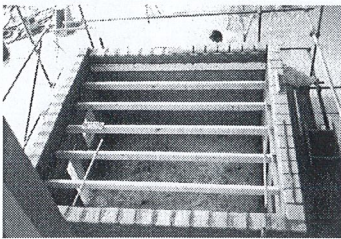
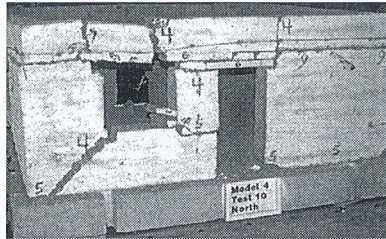


Getty Seismic Adobe Project (GSAP)

The Getty Conservation Institute, USA
(This programme has been undertaken
before the seism of Northridge of
January 1994)

Los Angeles, USA, 1990

12 years of research and tests
including seismic prevention and post-
seism intervention (*retrofitting*) on the
adobe historical heritage of California



3 publications :

*Survey of damage to historic adobe
buildings after the January 1994
Northridge Earthquake*

*Seismic stabilization of historic adobe
structures*

*Planning and Engineering Guidelines
for the Seismic Retrofitting of historic
adobe structures*

TERRA 2003, YAZD, IRAN

9th International Conference On The Study And Conservation Of Earthen Architecture

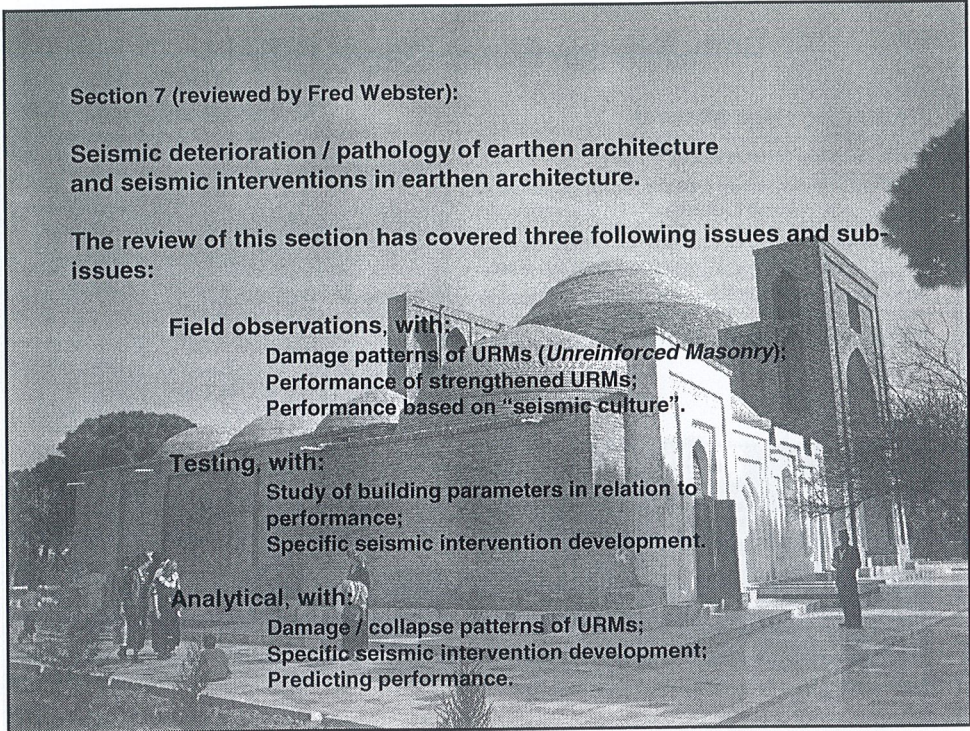
Research in earthen architecture conservation : a literature review

Hubert Guillaud and Erica Avrami
as editors

Claudia Cancino, Hubert Guillaud, Richard Hughes, Anne Oliver, Leslie Rainer,
Brian V. Ridout, Bruce Velde, and Fred Webster
as contributing authors

Project TERRA
CRATerre-EAG - Getty Conservation Institute - ICCROM

The Power point presentation has been prepared by: Hubert GUILLAUD and Alba RIVERO OLMOS
CRATerre-EAG, B.P. 6039, F- 38058, GRENOBLE, FRANCE
Special thanks for exceptional photographs credits to:
Herman GASCHÉ (Roman Ghisla's archives on Chogha Zanbil archaeological campaign
Henriette SALA (Aerial view of the site of Susa, Kuzakhsan)



Section 7 (reviewed by Fred Webster):

Seismic deterioration / pathology of earthen architecture
and seismic interventions in earthen architecture.

The review of this section has covered three following issues and sub-issues:

Field observations, with:

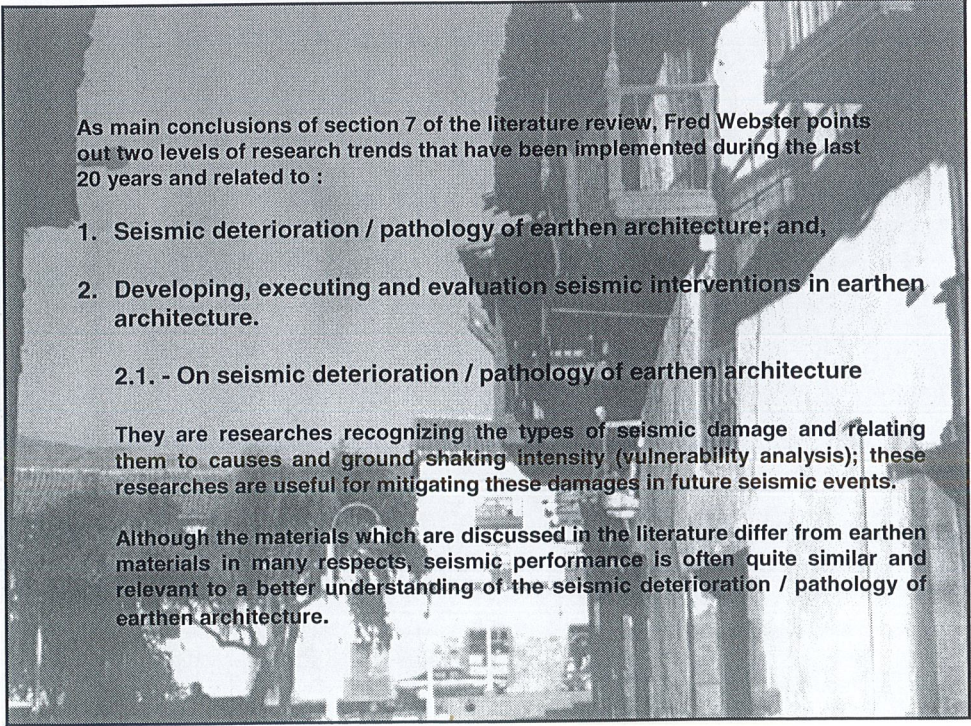
Damage patterns of URMs (*Unreinforced Masonry*);
Performance of strengthened URMs;
Performance based on "seismic culture".

Testing, with:

Study of building parameters in relation to
performance;
Specific seismic intervention development.

Analytical, with:

Damage / collapse patterns of URMs;
Specific seismic intervention development;
Predicting performance.



As main conclusions of section 7 of the literature review, Fred Webster points out two levels of research trends that have been implemented during the last 20 years and related to :

1. Seismic deterioration / pathology of earthen architecture; and,
2. Developing, executing and evaluation seismic interventions in earthen architecture.

2.1. - On seismic deterioration / pathology of earthen architecture

They are researches recognizing the types of seismic damage and relating them to causes and ground shaking intensity (vulnerability analysis); these researches are useful for mitigating these damages in future seismic events.

Although the materials which are discussed in the literature differ from earthen materials in many respects, seismic performance is often quite similar and relevant to a better understanding of the seismic deterioration / pathology of earthen architecture.

Conclusions of section 7 (following)

2.2. - Developing, executing and evaluation seismic interventions in earthen architecture

There are researches related to simple stability based interventions, such on wall center cores, partial roof diaphragms, strapping and through-wall ties.

Other researches are covering the introduction - or the continued use of traditional building methods - in areas where local seismic cultures are existing, to reduce the vulnerability of buildings.

There is also a research related to base isolation and SMADs (*Shape Memory Alloy Devices*) that are developed to improve the stability response of cultural heritage structures.

2.3. - And, as general conclusion:

The research efforts related to earthen architecture are consistent, but they may be extensively enhanced by looking to the several and varied research and testing efforts on stone and brick masonry interventions, most of which are applicable to earthen architecture as well.

Examples of recent projects

Public library (Peru)

Municipality of Huancayo
CRATerre America latina

Huancayo, Peru, 1985



- Compressed Earth Blocks masonry.
- Vertical and horizontal steel reinforcements.
- Ring-beams in reinforced concrete.
- Independent light wooden tower

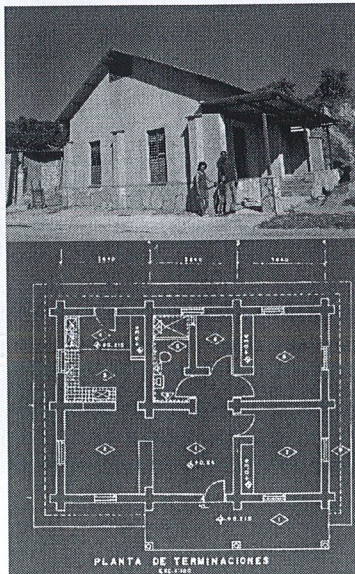
Adobe housing in la Calera, Cuba

ONG Habitat-Cuba and CRATerre-EAG, France

Santiago de Cuba, Cuba, 1997

Pilot project of 6 housing units

- Ground floors in light adobes and buttresses
- First floors in wooden framing infilled with earth (wattle and daub)
- Vertical and horizontal reinforcements
- Light roofing



Private houses based on the pilot project of Santiago (1998)

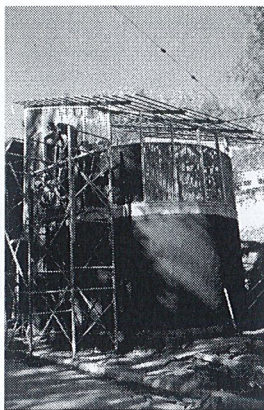


Implementing the peruvian standard on seismic-resistant adobe construction.

Social Centre of the UCA

- Universidad Simeon Canas, Salvador
- Misereor, Germany
- CRATerre-EAG, France

Salvador, 1995

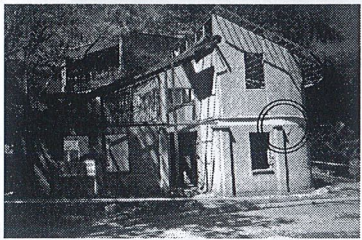


Ground floor
adobe and compressed
earth block masonry with
vertical and horizontal
reinforcements in bamboo

First floor
prefabricated wooden
pannels infilled with earth
(wattle and daub)



Arch Wilfredo Carrazas Aedo

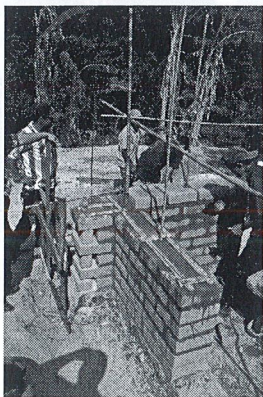


The same building after the seism of 2000
(7 on Richter's scale)

Seismic-resistant adobe housing project Project

Salvador, 2000

- Fundasal, Salvador
- Misereor, Germany
- CRATerre-EAG, France



Light adobes (very rich
in straw)

Vertical and horizontal
reinforcements in caña
brava

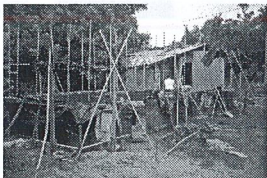
Buttresses

Light roofing



Arch Wilfredo Carrazas Aedo

The prototype module built
during a training course



Development of housing projects based on the prototype

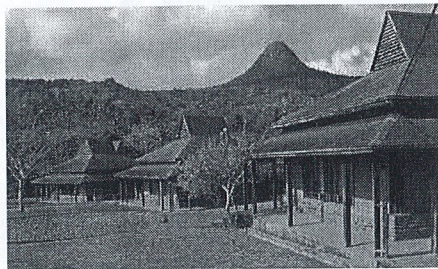
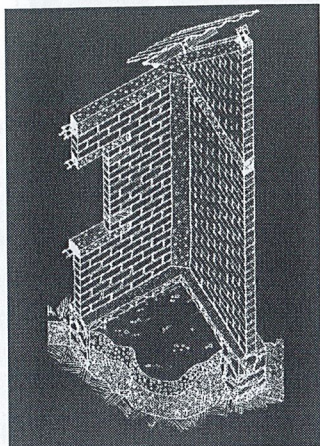
Social housing in Mayotte

- Real Estate Company of Mayotte (SIM), France
- CRATerre-EAG, France

Since the beginning of the 1980's

Development of the local earthen construction branch
(Compressed earth blocks)

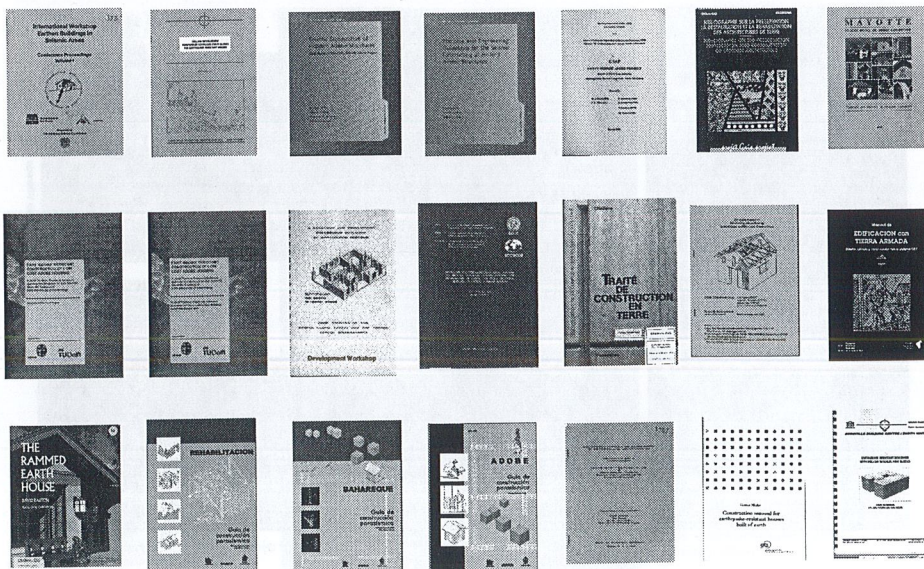
Design and construction of natural-disaster resistant housing
Answering to the French seismic and cyclonic building standards



More than 2000 housing units have been
derived from the proposed models



Bibliography of reference



PART 3 :

Earthquake resistant earthen construction

Bibliography of reference

All abstracts of the bibliographical sources have not been completed yet.

A comprehensive Study on Earthquake Disasters in Turkey in View of Seismic Risk Reduction / Sapporo, Department of Architectural engineering, 1983

Theme:

Language:

Abstract:

Adobe construction and its performance in southern california / O'Conner, Edward; Plecnik, Joseph; Chan, Hon M.; Baker, Treven E. / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, 1981, p. 293-310

Theme:

Language: English

Abstract: ICCROM

Discussion on the construction and performance of two adobe structures in southern California. First, the San Fernando mission is presented relative to its construction details and its performance and rehabilitation during and after the 1971 San Fernando earthquake. Second, an adobe home located near Oceanside, California, is discussed regarding its method of construction and performance under weathering and earthquakes since its construction in 1964.

Adobe constructions, basis for a seismic resistant code / Vargas, Julio / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, 1981, p. 457-502

Theme:

Language: English

Abstract: ICCROM

Comprehensive abstract of 7 years of work on design of adobe aseismic houses. Seismic resistant code proposed. Over thirty references.

Adobe, its permitted uses and research needs / Meehan, John F. / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, **1981**, p. 451-456

Theme:

Language: English

Abstract: ICCROM

Use of adobe in California. Reference to eight codes.

A field and laboratory tested technique for retrofitting abobe houses in seismic areas / Torrealva, D. / In: *Proceedings of the middle east and Mediterranean conference on earthen and low strength masonry buildings in seismic areas*, Ankara, Turkey, September **1986**

Theme:

Language: English

Abstract: Fred Webster

Following some field repairs done to buildings affected by the Popayan Earthquake in Colombia, tests were conducted at the PUCP in Lima of the very technique that had been used: placing wire mesh at the corners of the buildings and covering with a sand cement mortar. One model was tested without reinforcing, tested, repaired, and tested again, and a second was tested with the reinforcement from the beginning. The results show that in addition to the benefit of the wire mesh some new patterns of failure may be avoided by introducing additional features in the technique.

A history of reinforced masonry construction designed to resist earthquakes: 1755-1907 / Tobriner, S. / In: *Earthquake Spectra*, Vol. 1, N°1, EERI, November **1984**

Theme:

Language: English

Abstract: Fred Webster

The practice of reinforcing masonry buildings with wooden beams or metal bars or rods specifically for earthquake resistance was surveyed in the period of 1755 to 1907. This survey, which includes seismic resistant construction systems dating from 1755 illustrates how common sense solutions of reinforcing masonry structures were embodied in a seismic culture, and specifically that the most basic weakness in masonry, namely shear and tensile strength were addressed by the inclusion of vertical, diagonal, or horizontal elements attached to or embedded in the masonry walls.

A manual of historical seismography / Pierotti, P. / Edizioni Plus, Università di Pisa, Pisa, Italia, 2003

Theme:

Language:

Abstract:

Appropriate building codes and specifications for adobe construction / Machenry, Paul G., Jr / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, 1981, p. 425-450

Theme:

Language: English

Abstract: ICCROM

Examination of existing regulations in adobe constructions. The height of a wall must not be more than ten times the thickness. Specifications for untreated and reinforced materials proposed in detail.

Après un séisme : mesures d'urgence, évaluation des dommages / Pierre Pichard / in *Etudes et documents sur le patrimoine culturel*, vol.6, UNESCO, 1984

Theme:

Language:

Abstract: ICCROM

Technical information published under the auspices of unesco to indicate the emergency measures that can be taken after an earthquake to protect the damage heritage and to facilitate later repair and preservation work. The document deals with both immovable and movable property.

Arabian mud brick technology : some thoughts after the Bam earthquake / Archie G. Walls / Forthcoming.

Theme:

Language: English

Abstract: Author

The aim of this article is to explain the layered technique which the author first noted in Oman in 1977, its characteristics and materials, its geographical distribution and chronological record. The article concludes with references to the restoration of Arad Fort, Bahrain, and some thoughts on their relevance to future works at Bam.

A review of the seismic behaviour of earthen housing in Nicaragua / Penalba, Celina U. /
In: *Earthen buildings in seismic areas. Proceedings of the international workshop held
at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington:
National science foundation, **1981**, p. 311-333

Theme:

Language: English

Abstract: ICCROM

Description of efforts to make earthen construction safer appropriate for energy conservation and suitable for using alternate forms of energy. Reference is made on two types of building: the taquezal (wattle and daub), and, adobe.

**A strategy for developing indigenous building in earthquake regions – Case studies of
the Bandar Abbas (1977) and the Zarand (1978) earthquakes** / Afshar, F. ; Cain,
A. ; Daraie, M.R. ; Norton, J. / Development Workshop.

This document has been published as “*Mobilizing indigenous resources for earthquake
construction*”.

**Behaviour observed in earthen buildings during four destructive earthquakes in Latin
American countries** / Balseiro, Carlos N.; Cano, Jose Herrera; Giuliani, Hugo / In:
*Earthen buildings in seismic areas. Proceedings of the international workshop held at
the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National
science foundation, **1981**, p. 19-95

Theme:

Language: English

Abstract: ICCROM

Review of the behaviour of earthen building during four earthquakes in Latin America. These are: San Juan, Argentina, 15 January 1944; Lima, Peru, 3 October 1974; Guatemala, central America, 4 February 1976.

Bibliography on the preservation, restoration and rehabilitation of earthen architecture
/ CRA Terre-EAG, Grenoble, France; ICCROM, Rome, Italy / Rome, **1993**

Theme:

Language:

Abstract:

Bricks, mortar and earthquake: historic preservation vs. earthquake safety / Langenbach
Randolph / In: *APT Bulletin*, n°31, **1989**, pp.30-43

Theme:

Language:

Abstract:

Buena tierra, apuntes para el disno y construccion con adobe, consideraciones sismorresistentes / Urbano Tejada Schmidt / CIDAP, Lima, Peru, 2001

Theme:

Language: Spanish

Abstract: Matthieu Dupont de Dinechin

This book tries to make a synthesis of all the studies, researches and publications done about adobe buildings regarding to earthquake resistance in Peru in the last 30 years. This is a design and building handbook for adobe, with focuses on seismic design. It also describes wattle and daub building methods developed in Peru.

Building construction under seismic conditions in the Balkan region. Volume 3, design and construction of stone and brick-masonry buildings / UNDP-UNDIPO Project RER-79-015 / Vienna: UNIDO, 1985

Theme:

Language: English

Abstract: ICCROM

A handbook of information on the analysis, design and construction of earthquake resistant masonry buildings. Contents: analysis of damage pattern and possible causes of failure; materials and construction systems; design assumptions and procedures; analysis and design of structural walls; foundations, floors, tie-beams, roofs and non-structural elements; presentation of design examples.

Building construction under seismic conditions in the Balkan region. Volume 6, repair and strengthening of historical monuments and buildings in urban nuclei / UNDP-UNDIPO Project RER-79-015 / Vienna: UNIDO, 1984

Theme:

Language: English

Abstract: ICCROM

This volume covers seismic strengthening of structures of historical or architectural value. After discussion of the general principles, it describes the typical structural forms and their seismic behaviour, the methods of analysis and investigation and the techniques for emergency intervention, repair and strengthening. Illustration of case studies from various Balkan countries.

Building for safety compendium. A annotated bibliography and information directory for safe building / Clayton, A. & Davis, I. / Exeter: Intermediate technology publications, 1994

Theme:

Language:

Abstract:

Building materials for post-earthquakes reconstruction in N.W. Iran / Mohan Rai / In *Low-cost housing and infrastructure. New Delhi, 28 – 30 March 1994. New Delhi: Indian National Academy of Engineering – Building Materials and Technology Promotion Council*

Theme:

Language:

Abstract:

Close range photogrammetrics analysis of earthen buildings under seismic loading / Cuny, Frederick C.; Mugnier, Clifford J. / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, 1981, p. 131-138

Theme:

Language: English

Abstract: ICCROM

Description of an interject project to demonstrate the feasibility of a new analytical technique for evaluating the performance of earthen buildings and other non-instrumentable structures subjected to earthquake induced loads.

Cluster layouts: a basis for the design of (earthen) structures in urban dwelling environments / Butler, Mark H. / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, 1981, p. 45-57

Theme:

Language: English

Abstract: ICCROM

Cluster layouts for houses in urban dwelling environments are proposed.

Conception parasismique pour la construction neuve et ancienne. / Séminaire parasismique 19 – 20 Novembre 1998. Villefontaine: Les Grands Ateliers de l'Isle d'Asbeau, **1998** - CD rom.

Theme:

Language:

Abstract:

Comment réparer les bâtiments endommagés par un séisme / New York: Publication des Nations Unies, **1977**

Theme:

Language:

Abstract: ICCROM

A handbook of repair techniques for earthquake damaged structures: masonry, adobe and reinforced concrete buildings are considered are analyzed - trilingual text: English, French, and Spanish - repair schemes with detailed illustrations are given at the end.

Conservation principles applied to seismic retrofitting of culturally significant adobe buildings. / Kimbro, Edna E. / In: *Conference on seismic retrofit of historic buildings, San Francisco, Nov. 18-19, 1991.*, San Francisco, **1991**

Theme:

Language:

Abstract: ICCROM

Seismic retrofitting of culturally significant adobe buildings presents designers with tremendous challenges to ensure life safety while respecting inherent cultural values. The nature of those values and the architectural conservation principles followed to maximize the preservation of historic fabric and safeguard authenticity are discussed to further sound preservation planning of seismic retrofitting interventions. The necessity of a multidisciplinary approach and the value of historic structure reports are emphasized ; relevant use issues are discussed.

Consolidation des maisons à parois en terre crue endommagées par des séismes / Diaconou, Daniel; Rosu, Elena , In: *Bulletin d'information CRATerre-EAG*, n. 14, **1994**, p. 8

Theme:

Language:

Abstract:

Construction manual for earthquake-resistant houses built of earth / Gernot Minke /
Eschborn: Gate-Basin, 2001

Theme:

Language:

Abstract:

Damage to historic adobe buildings near the epicenter of the 1989 Loma Prieta earthquake Santa Cruz County, California / Kimbro, E. E. / In: *6th international conference on the conservation of earthen architecture: Adobe 90*, Las Cruces, New Mexico, 14-19 October 1990, preprints 1990, pp. 327-330.

Theme:

Language:

Abstract:

Design, construction, behaviour and repair problems of rural structures in greece / Kalevras, Vladimir C. / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, 1981, p. 185-213

Theme:

Language: English

Abstract: ICCROM

Classification of different low-cost construction systems used in greece with reference to their problems, design construction, seismic behaviour, repair, and the needs for recommendations concerning these problems.

Design in retrofit and repair / in *Earthquake spectra, vol.10 n°1, feb 1994*. Oakland: Earthquake Engineering Research Institute, 1994

Theme:

Language:

Abstract:

Development and utilization of a "poured adobe" building system for seismic areas / Nelson, Lynn S. / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, **1981**, p. 275-283

Theme:

Language: English

Abstract: ICCROM

Description of the development, testing and use of a poured adobe building system made on-site earth as a low-cost, energy-efficient building material for seismic areas.

Development of sites for low-cost house in disaster / Mohan Rai / In: *Low-cost housing and infrastructure. New Delhi, 28 – 30 March 1994. New Delhi: Indian National Academy of Engineering – Building Materials and Technology Promotion Council*

Theme:

Language:

Abstract:

Disasters, a bibliographic guide / Bradford: University of Bradford disaster prevention and limitation unit, **1991**

Theme:

Language:

Abstract:

Disaster risk management, working concept / Wolfgang Garatwa, Christina Bollin. Eshborn: GTZ, **2002**

Theme:

Language:

Abstract:

Diseno sismico de construcciones de adobe y bloque estabilizado / Yamashiro, Ricardo; Sanchez, Alejandro; Morales, Roberto / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, **1981**, p. 449-508

Theme:

Language:

Abstract: ICCROM

Critical stresses on adobe constructions are identified from failure mechanism during earthquakes and in the laboratory. Masonry and cane strength are tested. New design for adobe housing. Blocks of reinforced adobe tested. A second part deals with roofing.

Dissesti e consolidamenti in zone terremotate / Ormea, G.B. ; Reverberi, U. / Milan: Ulrico Hoepli Editore, **1982**

Theme:

Language:

Abstract : ICCROM

Masonry structures: different kinds of failures. Foundation structures. Failures in reinforced concrete structures. Load bearing walls, arches and vaults, staircases. Strengthening systems for masonry and rc structures. Temporary supports and scaffolding. Code of practice for masonry building in seismic areas.

Earthen buildings and earthquakes / Blum, John A. / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, **1981**, p. 95-114

Theme:

Language:

Abstract: ICCROM

Prevention of damage in earthen construction while using, to a large extent, local materials and construction practices. The major contributors to damage and collapse are listed as well as the major ways to prevent collapse.

Earthen buildings in seismic areas of turkey / Aytun, A. / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, 1981, p. 345-372

Theme:

Language: English

Abstract: ICCROM

Adobe buildings in seismic areas of turkey are analyzed after quake. Examples of earthquake damage. A seismic design of roofs. 4 references.

Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981 / Washington: National science foundation, 1981 ; 3 vol., 27, 5 cm International Workshop on Earthen Buildings in Seismic Areas, Albuquerque.

Theme:

Language: English

Abstract: ICCROM

Fifty-five communications on five topics: structural problems; Materials; Social, economic and cultural aspects; Implementation; Codes, specifications and standards.

Earthquakes and adobe structures / Vargas Neumann, J. / In: Adobe: international symposium and training workshop on the conservation of adobe, Lima - Cuzco, Peru, 10-22 September 1983, Final report and major papers, 1983, pp. 69-75

Theme:

Language:

Abstract: ICCROM

A study on the seismic behaviour of adobe constructions, through tests performed at the engineering department of the catholic university of peru. Two different technologies were taken into account: masonry structures (adobe and "tapia"), and continuous systems (wood or cane with mud). Test results are reported and discussed, with suggestions for protection measures.

Earthquakes and adobes: effects and systems for intervention / Crosby, A. / In: *Cultural resource management: conserving earthen architecture*, 22, no. 6, 1999, pp. 39-44.

Theme:

Language:

Abstract:

Earthquakes and residential construction in japan / Scawthorn, Charles / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, **1981**, p. 347-369

Theme:

Language: English

Abstract: ICCROM

Earthquake damage models for wooden framed adobe houses in japan are presented. Survey on seismic damage on low-rise building is done through statistical analysis.

Earthquakes in Turkey: reconstruction problems, damage prediction, and recovery forecasting for earthen structures / Mitchell, William A.; Weida, William F. / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, **1981**, p. 305-333

Theme:

Language: English

Abstract: ICCROM

Survey on reconstruction after earthquake in turkey. Damage on various type of houses estimated. Two model proposed for damage prediction and recovery forecasting. 18 references.

Earthquake hazards to the earth buildings in Ningxia / Bai, Mingxue , In: *Proceedings of the international symposium on earth architecture, 1-4 November, 1985, Beijing* / Beijing: The Architectural Society of China, **1985**, pp. 55-63

Theme:

Language: English

Abstract: ICCROM

Identification of main defects and structural weaknesses in earthen buildings with reference to the recommendations of the ministry of housing, peru, and, the united nations experimental project for housing.

Earthquake resistant construction of earthen housing / Arya, A.S.; Boen, T. , In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, **1981**, p. 1-18

Theme:

Language:

Abstract: ICCROM

Identification of main defects and structural weaknesses in earthen buildings with reference to the recommendations of the ministry of housing, Peru, and, the united nations experimental project for housing

Earthquake resistant construction of low-cost adobe housing. Final Report and Annexes to Final Report / A.W.M. Kok, G. Sovero / Delft: CICAT, **1996**

Theme:

Language: Spanish (2 first chapters in English)

Abstract: Matthieu Dupont de Dinechin

This research has been realized as a joint venture between the Instituto de Investigacion Universidad y Region (IIUR) of the Universidad Nacional de San Antonio Abad del Cusco in Peru and the Delft University of Technologies in the Netherlands. The objective was to elaborate and verify alternative technologies for construction of new 2 story houses of earth and repair/reinforcement of existing ones, which can resist seismic loads. Meanwhile, computer models were developed and verified to analyze simple and refined forms of the construction. The solutions were 1) for new houses: first floor of rammed earth reinforced with wooden posts, second floor of wattle and daub. 2) for repair/reinforcement: sheeting of mortar above a wire netting, or vertical and horizontal wooden reinforcement as a supporting structure. This second solution, though effective, appeared difficult to implement.

Earthquake resistant provisions for adobe construction in Peru / Bariola, J. ; Vargas, J. ; Torrealva, D. ; Ottazi, G. / In: proceedings of the ninth world conference on earthquake engineering, Tokyo/Kyoto, Japan, August **1988**

Theme:

Language: English

Abstract: Fred Webster

This paper summarizes research that has led to the Earthquake-Resistant Provisions for Adobe Construction in Peru. The important effect of drying shrinkage of adobe mortar on eventual masonry strength is discussed, as well as the use of cane reinforcement for safety against collapse. The object of the paper is to present and discuss new earthquake-resistant provisions for adobe construction approved by the National Institute of Research and Standards for Housing in Peru.

Earthquake resistant rammed-earth (tapial) buildings / Vargas-Neumann, J. / In: proceedings of the 7th international conference on the study of the conservation of earthen architecture, Terra 93, Portugal, October **1993**, p. 503-508

Theme:

Language: English

Abstract: Fred Webster

This paper attempts to fill some gaps in the literature concerning earthen construction in seismic areas. Tapial, or rammed earth, has moderately low compressive strength and very low tension and shear strengths, but has acceptable drying shrinkage. The report summarizes studies on rammed earth structures including properties of the soil and shear tests on full-scale walls.

Edificacion con Tierra Armada, Diseño, calculo y construccion con el sistema CET/
Jorge Luis de Olarte Tristan, Evelin Guzman Shigetomi, Madrid **1993**

Theme:

Language: Spanish

Abstract: Matthieu Dupont de Dinechin

This manual is a result of a research program initiated in 1988 in the UNI (Universidad Nacional de Ingenieria), Peru, continued in the CISMID (Centro peruano-japones de Investigaciones Sismicas y Mitigacion de Desastres), and completed in Spain with the support of the CSIC (Instituto de Ciencias de la Construccion Eduardo Torroja). The CET system (Componentes Estructurales con Tierra) is a modular building system with a first floor of rammed earth and a second floor of wattle and daub. The system is described, with the result of several seismic tests. Then is explained how to design buildings with CET, how to calculate it and finally how to build it.

Engineering Geology and Geotechnical Aspects of Bam Earthquake / Kambod Amini Hosseini, Mohammad Reza MahdaviFar, Mohammad Keshavarz Bakhshayesh, Masomeh Rakhshandeh, International Institute of Earthquake Engineering and Seismology, Preliminary Report, **January 2004**

Theme:

Language:

Abstract:

Estudio sismico de construcciones de adobe de los pisos / Torres, Rafael E.; Sanchez, Alejandro; Morales, Roberto / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, **1981**, p. 387-407

Theme:

Language:

Abstract: ICCROM

Method to determine compression, shear and flexure in two story adobe dwellings. Seismic design and material characteristics suggested, for low cost housing.

Experimental determination of the seismic resistance of repaired masonry structures / Benetti, D. and Castellani, A. / In: *Proceedings of the seventh world conference on earthquake engineering*, Istanbul, Turkey, **1980**

Theme:

Language: English

Abstract: Fred Webster

Three commonly used repair techniques are the subject of an investigation on half scale models of typical rural masonry houses without rigid slabs. Cement grouting, external and internal steel tendons, drilled tendons, insertion of reinforced concrete columns, and replacement of wooden slabs with reinforced concrete ones were among those considered for study.

Experimental tests on masonry structures provided with shape memory alloy anti-seismic devices / Indirli, M. et al. / In: *proceedings of the twelfth world conference on earthquake engineering*, New Zealand society for earthquake engineering, Upper Hutt, New Zealand, **2000**

Theme:

Language: English

Abstract: Fred Webster

The uses and effects of Shape Memory Alloy Devices (SMADs) are investigated in three scenarios: 1) shaking table tests on masonry wall mockups simulating a cultural heritage structure, with SMADs working to prevent out-of-plane collapse, 2) large-scale tests on masonry walls with SMADs utilized to increase resistance and stability against in-plane earthquake forces, and 3) long-period tests for creep evaluation in a wall sample and brick columns. The SMADs prove to be very effective in all three areas

Experimental tests on seismic devices based on shape memory alloys / Dolce, M. ; Cardone, D. ; Nigro, D. / In: *proceedings of the twelfth world conference on earthquake engineering*, New Zealand society for earthquake engineering, Upper Hutt, New Zealand, **2000**

Theme:

Language: English

Abstract: Fred Webster

Many nickel-titanium alloy elements were tested to find the best way to exploit the peculiar properties of SMAs. They differed in shape, composition, and stress state. The most significant findings were: extreme versatility, fatigue resistance, durability, and long term reliability.

Fundamentos de ingenieria sismica vol.1, Introduccion a la sismologia / Franz Sauter. Cartago: Editorial tecnologica de Costa Rica, **1989**

Theme:

Language:

Abstract:

Getty seismic adobe project, report of third year activities. Shaking table tests of large scale adobe structures / Ginell, W.S. ; Tolles, E.L ; Gavrilovic, P. ; Kretevska, L. ; Sendova, V. ; Taskov, L. / Los Angeles: GCI, **2001**

Theme:

Language:

Abstract:

Guide de construction parasismique. Adobe / Carazas Aedo, W. / Villefontaine: CRATerre-EAG, **2002**

Theme:

Language:

Abstract:

Guide de construction parasismique. Réhabilitation / Carazas Aedo, W. / Villefontaine: CRATerre, **2002**

Theme:

Language:

Abstract:

Guide de construction parasismique. Torchis / Carazas Aedo, W. / Villefontaine: CRATerre, 2002

Theme:

Language:

Abstract:

Guidelines for building measures after disasters and conflicts / Horst Valentin Kreutner, Birgit Kundermann, Kiran Mukerji. München : GTZ, 2003

Theme:

Language:

Abstract:

Great dimension earth construction in the XIX century in northern Chile / Munoz Gonzales E. ; Bahamondez Prieto M. / In: Preprints of the 9th International Conference on the Study and Conservation of earthen Architecture, 29 November – 2 December 2003, Yazd, Iran

Theme:

Language:

Abstract:

Improving earthen housing to better withstand earthquakes / Hartkope, Volker / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, 1981, p. 279-303

Theme:

Language: English

Abstract: ICCROM

Improved design for adobe housing against earthquakes blocks consolidated with asphalt. Design and construction details clearly shown. 19 references.

Indigenous Building Techniques of Peru and their potential for improvement to better withstand earthquakes / Hartkopf, V. / Washington: Agency for international development, 1981

Theme:

Language:

Abstract:

International recommendations for design and erection of unreinforced and reinforced masonry structures / Haseltine B.A., Rotterdam: CIB, 1987

Theme:

Language:

Abstract:

International workshop on earthen buildings in seismic areas. Conference report / , In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, 1981, p. 2-90

Theme:

Language:

Abstract: ICCROM

International workshop on earthen buildings in seismic areas. Conference report. State-of-the-art and research needs. Priorities and recommendations. Bibliography of 250 references.

Introduction à la construction parasismique en terre / Carazas Aedo, W. / Grenoble, 2000

Theme:

Language:

Abstract:

Investigaciones en adobe / Vargas, Julio N.; Ottazzi, Gianfranco / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, 1981, p. 409-447

Theme:

Language:

Abstract: ICCROM

Recommendations for adobe constructions based on natural scale tests. Walls reinforced with wood and canes. Various kind of compression tests. Evaluation of results.

La arquitectura de Quito frente a los sismos / del Pino I.; de Sutter, P.; and Moran P. M. / In: *6th international conference on the conservation of earthen architecture: Adobe 90*, Las Cruces, New Mexico, 14-19 October 1990, preprints 1990, pp. 316-321

Theme:

Language:

Abstract:

La problemática de la conservación de edificios históricos de mampostería técnicas constructivas y códigos utilizados en antigua-guatemala / Ordonez, Marco; Tului, Castellanos / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, **1981**, p. 639-658

Theme:

Language: English

Abstract: ICCROM

Preservation of monumental site of la antigua in seismic area. Traditional materials and construction methods, damages by earthquakes and restoration techniques are analyzed.

Learning from past earthquakes: case histories in Iran / Eshghi, S. ; Zare, M. / In: Proceedings of the 10th European conference on earthquake engineering, Vienna, Austria, 28 august, 2 September 1994, ed. A A Balkema, Rotterdam, **1995**, Vol.1, pp. 799-804

Theme:

Language:

Abstract:

Lessons from recent earthquakes in southern Italy and observations about the performance of buildings of traditional construction in these events / Norsa, Aldo / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, **1981**, p. 285-292

Theme:

Language: English

Abstract: ICCROM

Discussion on the behaviour of different building types and construction techniques with reference to the earthquake of campania/ basilicata, 23 november 1980, and, belice, 14 - 15 january 1968.

Adobe housing reconstruction after the 2001 El Salvador Earthquake / Dowling D. / In: Lessons learned over time, Volume V, Earthquake Engineering Research Institute, National Science Foundation, **2004**

Theme:

Language:

Abstract:

Local seismic culture, ancient buildings and earthquakes / European University Centre and Council of Europe, 1997

Theme:

Language:

Abstract:

Mesure a prendre en cas de seisme dans le domaine du patrimoine culturel / Foramitti, Hans , 1976

Theme:

Language:

Abstract:

Mitigating roof collapse in adobe dwellings / Mostaghel, N.; Khojasteh-Bakht, M. , In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, 1981, p. 259-273

Theme:

Language: English

Abstract: ICCROM

Proposals to mitigate roof collapse due to earthquakes for rural housing in desert regions of Iran. The plan provides for villagers to build their own housing, using local construction materials and traditional techniques.

Mobilizing indigenous resources for earthquake construction / Afshar, F. ; Cain, A. ; Daraie, M.R. ; Norton, J. / In: *Housing Science*, Vol. 2, N°4, Pergamon press, 1978, pp. 335-350

Theme:

Language: English

Abstract: Authors

“This paper discusses indigenous village building methods in earthen-quake regions. The paper proposes a methodology for upgrading of village building, to better withstand earthquakes, involving local people themselves and materials and technologies which remain in their hands. This paper is prepared in light of a survey carried out in the area of the Bandar Abbass earthquake in March 1977 in southern Iran. The second part of this proposes a methodology for the introduction of improved building techniques into earthquake areas. A programme of short training workshops held in rural areas, in which village builders participation is proposed as a way of upgrading indigenous building techniques. Through the development of indigenous building methods solutions can be reached which are economically, socially, and environmentally suited to the region and remain within the control of local people.”

Non-Engineered construction in developing countries: an approach toward earthquake risk reduction / Arya, A.S. / In: Proceedings of the Twelfth World Conference on Earthquake Engineering, New Zealand Society for Earthquake Engineering, Upper Hutt, New Zealand, **2000**

Theme:

Language:

Abstract: Fred Webster

Issues regarding the earthquake risk reduction of non-engineered buildings are delineated including pre-disaster mitigation and preparedness, damage reduction initiatives through building codes and guidelines. Major causes of damage to non-engineered buildings in past earthquakes is presented and critical interventions into new constructions are highlighted. Practical earthquake resistant schemes in new buildings and retrofitting of unsafe buildings is outlined.

Passive seismic devices based on shape memory alloys / Dolce, M. and Marnetto, R. / In: Proceedings of the Twelfth World Conference on Earthquake Engineering, New Zealand Society for Earthquake Engineering, Upper Hutt, New Zealand, **2000**

Theme:

Language: English

Abstract: Fred Webster

Shape Memory Alloy Devices can provide a wide range of performances, from full re-centering to high energy dissipation capabilities, as well as high resistance to large strain cycles fatigue and great durability. This paper describes the conceptual design and practical implementation of these new passive seismic control devices.

Peru: la restauracion de monumentos historicos contruidos con adobe y las tecnicas utilizadas / Samanez Argumedo, Roberto / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, **1981**, p. 565-614

Theme:

Language: English

Abstract: ICCROM

Historical and typological description of adobe buildings in peru. Restoration of adobe monuments. Case tests. Description of the major projects of adobe restoration in peru.

Planned testing program on the roorkee shock table / Keightley, W.O. / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, **1981**, p. 215-226

Theme:

Language: English

Abstract: ICCROM

This paper lists a number of alternatives concerning how to test and what to test on a program of testing earth or low grade masonry structures, from which the testing program may be determined.

Planning and engineering guidelines for the seismic retrofitting of historic adobe structures/ E Leroy Tolles, Edna E. Kimbro, William S. Ginell. The Getty conservation institute, Los Angeles, **2002**

Theme:

Language:

Abstract:

Possibilites d'intervention de la photogrammetrie apres un seisme pour sauvegarder l'heritage des biens culturels / Foramitti, Hans , **1976**

Theme:

Language:

Abstract:

Prevención sismica en las construcciones de adobe, en la ciudad de Guatemala después de los terremotos de 1917-1918 / García, M. E. M. / In: *6th international conference on the conservation of earthen architecture: Adobe 90*,. Las Cruces, New Mexico, 14-19 October 1990, preprints **1990**

Theme:

Language:

Abstract:

Principes directeurs pour la prévention des catastrophes. Vol.2, Mesures en matière de construction visant à limiter les effets des catastrophes / Bureau du coordinateur des Nations Unies pour les secours en cas de catastrophes / Genève: Nations Unies, **1976**

Theme:

Language:

Abstract:

Principles and Regulation of Design and Construction of Masonry Buildings / Shakib, H.
; Ghatee, P. ; Majedi Ardakani, M.H. / I. R.Housing Foundation, The Interior Ministry

Theme:

Language:

Abstract:

Programma de reconstruccion de viviendas en El Salvador. Modulos sismoresistentes en tierra: Adobe y bahareque Ceren / FUNDASAL, Misereor, CRATerre-EAG. San Salvador, 2001 – CD avec deux vidéos

Theme:

Language: Spanish

Abstract: Matthieu Dupont de Dinechin

Those 2 videos are part of an earthquake resistant houses reconstruction program in Salvador. The purpose is communicational, but the videos are presented as a manual for building earthquake resistant one-storey houses in adobe or wattle and daub. After an introduction explaining the context, each step of the construction process, from the foundations to the roof, is described, with focus on the specific topics regarding quality, like the choice of the materials.

Rebuilding and resettlement, 9 years later; a case-study of the contractor built reconstruction in Yemen, following the 1982 Dhamar earthquake / Barakat, S. / York: IAAS. Post-war reconstruction & development unit, 1993

Theme:

Language:

Abstract:

Reconstruccion de vecindades since the 1985 mexican earthquakes / In: Earthen buildings in seismic areas / 1987

Theme:

Language:

Abstract: ICCROM

Earthen buildings fared better than other structures following the september 1985 earthquake in mexico city. Tenement buildings with adobe partition walls, "vecindad", were however damaged. This articles gives a brief history of the "vecinda" and the political events surrounding their reconstruction.

Recomendaciones para las construcciones de adobe en regiones sismicas / Crisosto, Luis /
In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, **1981**, p. 389-423

Theme:

Language: English

Abstract: ICCROM

Booklet of popular recommendations on how to build an adobe house. A lot of drawings and practical advises.

Reinforced poured adobe and its applicability to earthquake resistant construction /
Webster, Frederick A. / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of New Mexico, Albuquerque, may 24-28, 1981* / Washington: National science foundation, **1981**, p. 675-693

Theme:

Language: English

Abstract: ICCROM

Poured adobe walls, with steel wire or, better bamboo reinforcing is proved to satisfy the uniform building code even in high seismic zones. Technical details for construction. Finer reinforcing analyzed

Repair and retrofit of unreinforced masonry structures / Manzouri, T. ; Schuller, M.P. ;
Shing, P.B. ; Amadei, B. / *Earthquake spectra*, Vol. 12, N°4, EERI, November **1996**

Theme: D4

Language: English

Abstract: Fred Webster

A study of different repair and retrofit techniques for unreinforced masonry structures was conducted to identify suitable grouting materials and procedures and to develop analysis tools to evaluate performance before and after retrofit. Various grouting materials and procedures were evaluated using material tests, masonry component tests and shear wall tests. The test results showed that the strength and stiffness of damaged walls can be restored with grout injection, and that strength and ductility can be greatly enhanced by introducing steel reinforcing.

Research related to seismic deterioration/pathology of Earthen Architecture and Seismic Intervention in Earthen Architecture / Fred Webster, Terra Literature Review

Theme:

Language:

Abstract:

Research and promotional requirements for earth buildings in developing countries /

Carlson, Eric / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of new mexico, albuquerque, may 24-28, 1981* / Washington: National science foundation, **1981**, p. 259-578

Theme:

Language: English

Abstract: ICCROM

Review of utilization of cinva-ram soil cement block maker and asphalt adobe in the world. Main construction defect listed. Suggestions for low-cost housing plans. 17 references.

Revaloriser la culture constructive parasismique pour l'habitat contemporain à Liberia-Guanacaste (Costa Rica) / Chacon Achi, X. / TPFE, Ecole d'architecture de Grenoble, **2004**

Theme:

Language:

Abstract:

Seismic behavior of blocky masonry structures / Azevedo, J. ; Sincaian, G., Lemos, J.V. / In: *Earthquake spectra*, Vol. 16, N°2, EERI, may **2000**

Theme:

Language: English

Abstract: Fred Webster

The discrete element method analysis technique is used to analyze the seismic behaviour of masonry structural systems. It is shown that the method is able to reproduce the important phenomena of crack opening and joint sliding. One of the goals of this research was to assess the collapse patterns of different structural elements when subjected to self-weight and seismic action, starting with simple arches and columns and progressing to more complex structures, such as a bell tower and an aqueduct. The analysis method also allows for the inclusion of tension reinforcing elements so that different retrofit schemes can be studied and mitigating effects compared.

Seismic design for earthen, New Mexico & Arizona, seismic zone 2 / In: Adobe today....

Theme:

Language:

Abstract:

Seismic Protection of Cultural Heritage Using Shape Memory Alloy Devices – An EC Funded Project (ISTECH) / Castellano, Indirli, Martelli, Azevedo, Sincraian, Tirelli, Renda, Croci, Biritognolo, Bonci, Viskovic. In: *Proceedings of the International Post-SmiRT Conference Seminar on Seismic Isolation, Passive Energy Dissipation and Active Control of Vibrations of Structures. Cheju, Korea, August 1999.*

Theme:

Language: English

Abstract: Fred Webster

This European Commission funded project was meant to develop innovative techniques for the restoration of cultural heritage structures, primarily masonry buildings: The use of devices based on super-elastic shape memory alloys was shown to be effective in improving the resistance of masonry structures to earthquake shaking. These devices, known as Shape Memory Alloy Devices (SMADs) can be used to pre-stress masonry, yet avoid over-stress owing to the alloys' super-elastic force limitation, or plateau. Other types of SMADs are used in situations where no pre-stress is applied to the masonry and only become activated during dynamic loading.

Seismic risk reduction of old settlements and land-use in earthquake zones of the Mediterranean as leading components of the priority actions programme of M.A.P. / Pavicevic, Bozidar S. , In: *Proceedings of the 1st international seminar on modern principles in conservation and restoration of urban and rural cultural heritage in seismic-prone regions. Skopje, 17-22 October 1988., Skopje: RZZSK;IZIIS;ICCRUM, 1989, p. 233-242*

Theme:

Language:

Abstract: ICCROM

This paper briefly presents a review of some data concerning the Mediterranean Action Plan map (within the United Nations Environment Programme UNEP) and its priority action programme PAP, priority action "Land-use planning in earthquake zones: conclusions and recommendations of the 1985 Cetinje seminar; concise accounts on the 1986 Genoa seminar on seismic risk reduction in the Mediterranean region, and the (first) Split seminar (May 1985).

Seismic shaking table tests of retrofits for large-scale model adobe structures / Ginell, W. S.; Tolles, E. L.; Gavrilovic, P.; and Sendova, V. / In: *Terra 2000: 8th international conference on the study and conservation of earthen architecture. Torquay, United Kingdom, 11-13 May 2000, Preprints 2000, pp. 242-248*

Theme:

Language:

Abstract:

Seismic stabilization of historic adobe structures. Final report of the Getty seismic adobe project / E. Leroy Tolles, Edna E. Kimbro, Frederick A. Webster, William S. Ginell / In GCI Scientific Program Reports, The Getty conservation institute, Los Angeles, 2000

Theme:

Language:

Abstract:

Seismic strength of adobe masonry / Vargas Neumann, Julio; Bariola Bernales, Juan; Blondet, Marcial / In: *Earthen buildings in seismic areas*, 1984

Theme:

Language:

Abstract: ICCROM

Conclusions and recommendations of the research project on "earthen buildings in seismic areas", developed by the catholic university of peru. Having performed mechanical tests on adobe masonry, its character and strength have been determined, and suggestions for their improvement have been given.

Abstract: Fred Webster

The factors that influence the strength of adobe masonry are studied, including 1) material properties of the soil used, 2) drying process (issues of shrinkage cracking), 3) effect of additives such as lime, cement, and a dispersing agent such as sodium carbonate, and 4) the construction process. The most positive findings in each category are summarized.

Seismic tests of adobe walls / Bariola, J. and Sozen, S.A. / Earthquake Spectra, Vol. 6, N°1, EERI, 1990

Theme:

Language: English

Abstract: Fred Webster

Nine earthquake simulation tests were made to investigate the influence of: 1) type of ground motion; 2) slenderness ratio; and 3) wall thickness. Short specimens failed by overturning, tall ones by upper-level cracking. Results showed that failure depends primarily on motion type and wall slenderness ratio.

Shaking table tests of improved adobe masonry houses / Ottazzi, G. ; Yep, J. ; Blondet, M. ; Villa-garcia, G. ; Ginocchio, J. / In proceedings of the ninth world conference on earthquake engineering, Tokyo/Kyoto, Japan, August **1988**

Theme:

Language:

Abstract: Fred Webster

This report summarizes the findings from eight full-scale shaking table test done at PUCP in Lima. Along with control specimens constructed with traditional techniques, various improved construction techniques were tested and compared, including addition of straw and coarse sand to the mud mortar to reduce cracking, interior cane mesh and crowning tie-beam placement, and horizontal or vertical cane reinforcement. The interior mesh plus tie-beam solution seemed to give the best results.

Shaking table tests on 24 simple masonry buildings / Benedetti, D. ; Carydis, P. ; Pezzoli, P. /In: Earthquake engineering and structural dynamics, Vol. 27, John Wiley & Sons, 1998

Theme:

Language: English

Abstract: Fred Webster

24 half-scale model 2-story buildings were tested, repaired and strengthened, and tested again in 119 shaking table tests. The efficiency of various strengthening techniques used was studied, plus the change in dynamic properties of the systems with increasing levels of damage is described. The repair techniques used include local sealing of cracks with cement mixture, emaco or gypsum, steel "networks" (thin steel made into a mesh of approx. 5" openings) nailed-to the floor slabs and covered with a cement layer, and horizontal tendons applied at each story level. Simple methods were found to be quite efficient.

Sistemas estructurados de madera en iglesias de tierra del norte de Chile / González, E. M. and Prieto, M. B. / In : *Terra 2000: 8th international conference on the study and conservation of earthen architecture*. Torquay, United Kingdom, 11-13 May 2000, Preprints **2000**, pp. 249-253.

Theme:

Language:

Abstract: ICCROM

The proportion of earthen architecture of the towns of the semi-arid north of Chile that still survives attains a level of some 60 percent. These are adobe structures that were built from the early 19th century onwards. The setting for this earthen architecture is a rural environment, with a climate featuring low levels of precipitation and a problematic degree of seismic activity. When the latest earthquake took place in October 1997, it reached a level of 6.8 on the Richter scale and in its wake left eight people dead and thousands of families suffering the loss of their homes. It is in this setting that 72 churches and chapels that were damaged during the earthquake are located. Our professional team was given the task of restoring the six most important parish churches in the region. The aim of our published research is to provide an account of our experiences to date in assessing the condition of three churches, diagnosing their structural problems and undertaking their restoration. The research provides evidence of the effectiveness of complementary wooden construction systems that were designed for these earth buildings during the last century with the aim of mitigating the effects of earthquakes.

Sitting and structural aspects of adobe buildings in seismic areas / Gurpinar, Aybars; Erdik, Mustafa; Ergunay, Oktay / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of new mexico, albuquerque, may 24-28, 1981* / Washington: National science foundation, **1981**, p. 139-183

Theme:

Language: English

Abstract: ICCROM

Description of the experience of the turkish national committee on earthquake engineering in research and implementation of earthquake resistant design practice of adobe structures in turkey.

Sitting of adobe structures in earthquake prone areas / Raymond, Loren A. / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of new mexico, albuquerque, may 24-28, 1981* / Washington: National science foundation, **1981**, p. 335-346

Theme:

Language: English

Abstract: ICCROM

Discussion on structural and seismic factors with reference to topographic, lithologic aspects in selecting geologically safe construction sites away from fault zones, cliffs, unstable slopes, or areas with deep alluvial or man-made fills.

Social and cultural aspects of an earthquake resistant adobe housing program / Oakley, David / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of new mexico, albuquerque, may 24-28, 1981* / Washington: National science foundation, **1981**, p. 157-165

Theme:

Language: English

Abstract: ICCROM

Social and cultural aspects of reconstruction plans for resistant houses in adobe after earthquakes are discussed. No references.

Social aspects of post-disaster housing: implications for program planning / Snarr, D. Neil; Brown, E. Leonard / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of new mexico, albuquerque, may 24-28, 1981* / Washington: National science foundation, **1981**, p. 205-228

Theme:

Language: English

Abstract: ICCROM

Survey on the acceptability of new houses by the recipients after hurricane. Results may help post-disaster planning. 10 references.

Soil dynamics and the earthquake destruction of the earthen architecture of the Arg-é-Bam / Langenbach Randolph, Iranian Journal of Seismology and Earthquake Engineering, (**forthcoming**)

Theme:

Language: English

Abstract: Author

“The Arg-é-Bam is a remarkable example of earthen architecture and construction that was heavily damaged in the Bam earthquake of 26 december, 2003. This paper presents findings that the collapse of the walls was from a combination of the effect of (1) the additive changes made to the walls, particularly in recent restorations, and (2) extensive damage from termites and loss of the cohesion of the clay, all of which interacted with the unusually high frequency of the earthquake vibrations in such a way that many walls simply burst from the subsidence of their cores of clay. Concern is raised for similar risks to other earthen monumental structures from future earthquakes.”

Some thoughts on “adobe codes” / Fred Webster in: *Adobe codes, 3rd edition*, Bosque 1995

Theme:

Language: English

Abstract: Matthieu Dupont de Dinechin

The author passes through several topics of the UBC (Uniform Building Codes) of the USA, and specifically of the adobe codes, regarding to its relevance to earthen building in seismic areas. He shows that most of those codes are inappropriate and that there is a lack of codes about very important points specific to earthen buildings.

State-of-the art panel report on earthquake resistant rural structures / Yuzugullu, Ozal / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of new mexico, albuquerque, may 24-28, 1981* / Washington: National science foundation, 1981, p. 535-564

Theme:

Language: English

Abstract: ICCROM

Rural houses in various materials are considered with respect to earthquakes damage. Aseismic design reviewed.

Strengthening of adobe houses for seismic actions / Meli, R. ; Hernandez, O. ; Padilla, M. / In: *Proceedings of the international workshop on earthen buildings in seismic areas*, vol. 1, 1981

Theme:

Language: English

Abstract: ICCROM

Evaluation of the efficiency of three strengthening methods for adobe houses. The main objective of the tests was to avoid separation of the walls in the corners. Results indicated that reinforcement are efficient if increased at least twice by any of the methods studied; the most efficient being the welded mesh reinforcement.

Abstract: Fred Webster

Five scale models were tested on a shaking table set to the ground motions from three actual earthquakes, testing three strengthening methods: 1) reinforced concrete bond beam at the top of the walls, 2) welded wire mesh nailed to both faces of the walls and covered by mortar, and 3) steel rods tied to both faces in the upper part of the walls. Any method was found to be very effective, with the welded wire mesh being the most efficient.

Strength and Behavior of Unreinforced Masonry Elements / Abrahams, D.P. / In:
Proceedings of the tenth world conference on earthquake engineering, Balkema,
Rotterdam, Netherlands, **1992**

Theme:

Language: English

Abstract: Fred Webster

Previous tests on URM elements show that masonry walls or piers need not be considered brittle. Behavior under reversed and repeated cyclic forces was not influenced appreciably by previous damage. If masonry elements are not actually brittle, then the lateral strength of a system may be thought of as the combined strengths of all of its masonry elements. This paper steps away from the common code prescription that the structure has no capacity for inelastic deformation, nor does it redistribute stresses after initial cracking. Experiments described show the ability of URM walls to resist much more than cracking strengths and that there is gradual softening until the ultimate limit-state is reached. A solution to estimate post-cracking ultimate strength is presented.

Strength of earthen wall subassemblies: an experimental and analytical study / Gulkan,
P. and Gurdil, F. / In: *Proceedings of the ninth world conference on earthquake
engineering*, Tokyo/Kyoto, Japan, August, **1998**

Theme:

Language: English

Abstract: Fred Webster

An experimental study of the behaviour of square adobe wall panels subjected to a constant in-plane compression normal to the horizontal mortar joints and an incrementally applied diagonal load for compressive and shear forces similar to how they would be stressed in an earthquake. In addition, analytical finite element models of the wall panels were used to predict the behaviour. Correlation was made between the experiments and theoretical predictions by representing the adobe block material as elastic-plastic obeying Mohr-Coulomb failure envelope.

Survey of damage to historic adobe buildings after the January 1994 Northridge earthquake / Tolles, E. Leroy; Webster, Frederick A.; Crosby, Anthony; Kimbro, Edna E. / In GCI Scientific Program Reports. The J. Paul Getty Trust, Getty Conservation Institute, Los Angeles, **1996**

Theme:

Language: English

Abstract: Fred Webster

A damage survey of 19 historic adobes in the Los Angeles area following the devastating Northridge earthquake of 1994. Seismic performance on both the macro and micro levels were evaluated. Types of damage were categorized and an overall damage level was assigned to each building. Estimates of the ground shaking intensity were assigned to each building site, as well, and a relationship between the expected damage level and the ground shaking intensity was developed.

Technical building standard NTE E.080 ADOBE / Blasco, A.B. ; Amado, J.L. ; Travezaño et al. / Lima, Peru **2000**

Theme:

Language:

Abstract:

Technical Manual on Reinforcing Adobe Housing in the Coastal and Mountain Zones of Peru / Zegarra Luis, San Bartolomé Angel, Quiun Daniel, Giesecke Alberto, Schmitter Jorg-Peter,

Theme:

Language:

Abstract:

Technical Mission to Bam and its Citadel / Guillaud Hubert, CRATerre-EAG, In: *UNESCO-ICHO Joint Mission to Bam and Its Citadel, 22-26 january 2004*

Theme:

Language:

Abstract:

Testing methodologies for earthen buildings / Krawinkler, H. / In: *Seminario Latinoamericano de construcciones de tierra en areas sismicas*, Lima, Peru, 23-27 May 1983, **1983**, pp. 409-425

Theme:

Language:

Abstract: ICCROM

Description and evaluation of experimental techniques that can be employed for assessing the seismic behaviour of earthen building and their components. Cyclic loading testing of components and field techniques. The use of scale models for testing earth buildings.

The 3000-year-old History of an Arabian Mud Brick Technology / Walls Archie, Terra Conference Proceedings, Yazd, **2003**

Theme:

Language:

Abstract:

The Bam citadel, a comprehensive report / ICHO, **2004**

Theme:

Language:

Abstract:

The cultural context of earthen housing in seismic areas / Oliver, Paul / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of new mexico, albuquerque, may 24-28, 1981* / Washington: National science foundation, **1981**, p. 167-189

Theme:

Language: English

Abstract: ICCROM

Cultural context of adobe housing in seismic areas is analyzed in term of many parameters. 29 references better understanding of these may help reconstruction plans.

The effects of the 1976 Guatemalan earthquake on earthen houses in Guatemala / Bates, Frederick; Killian, Charles D. / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of new mexico, albuquerque, may 24-28, 1981* / Washington: National science foundation, **1981**, p. 229-246

Theme:

Language: English

Abstract: ICCROM

Effects of earthquake on adobe houses in guatemala through personal interviews. Adobe abandoned for concrete blocks and wood. Little use of a seismic design for adobe construction.

The extent of adobe use in the United States / Gerbrandt, Harold; May, Gerald W. / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of new mexico, albuquerque, may 24-28, 1981* / Washington: National science foundation, **1981**, p. 95-110

Theme:

Language: English

Abstract: ICCROM

An esteem of adobe houses in the south west usa is given. 17000 residences. 1500 new are built per year

The extent of the problem of earthen buildings in Greece / Carydis, Panayotis, Gr / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of new mexico, albuquerque, may 24-28, 1981* / Washington: National science foundation, **1981**, p. 115-129

Theme:

Language: English

Abstract: ICCROM

Study of earthen buildings with a load carrying system of clay with various admixtures, and, structures with an initial wooden load carrying system filled in with clay.

The precautions against the earthquake and the anti-seismic for Ningxia's earth architecture / Huo, F. and Cao, S.-K. / In: *Proceedings of the international symposium on earth architecture*. Beijing, China, 01-04 November 1985, The Architectural Society of China, Beijing, **1985**, pp. 115-123.

Theme:

Language:

Abstract: ICCROM

The mountainous regions of ningxia (north western china) is a highly seismic area. About 3 million of its population live in earth sheltered building: cave dwellings, vaulted caves with sun-dried bricks, and single storeyed houses with flat roofs on earth bearing walls. A reviews f earthquake damage related to the various building typologies with suggestion on building design and other measures for seismic.

The proof of the pudding / Davis, Ian / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of new mexico, albuquerque, may 24-28, 1981* / Washington: National science foundation, **1981**, p. 59-93

Theme:

Language: English

Abstract: ICCROM

The gaps between good ideas in a seismic constructions and their application is analyzed extensively. 32 references adobe design for new housing revised.

The Whittier Narrows, California Earthquake of October 1, 1987 – Evaluation of Strengthened and Unstrengthened Unreinforced Masonry In Los Angeles City / Deppe, K. / In: *Earthquake Spectra*, Vol.4, N°1, EERI, **1988**

Theme:

Language: English

Abstract: Fred Webster

Based on analysis done on the damage to unstrengthened as well as strengthened and tension anchored-only buildings in Los Angeles, this report attempts to determine the most effective ways of improving the design standards for strengthening URM's. Additional work is needed as a combined effort of City of Los-Angeles and SEAOSC.

The Whittier Narrows, California Earthquake of October 1, 1987 – Preliminary Evaluation of the performance of Strengthened Unreinforced Masonry Buildings
/ Moore, T.A. ; Kobzeff, J.H. ; Diri, J. ; Arnold, C. / In: *Earthquake Spectra*, Vol.4, N°1, EERI, 1988

Theme:

Language: English

Abstract: Fred Webster

There are 7000 URMs in the downtown Los Angeles area, and many of them were significantly damaged in the Whittier Narrows Earthquake. This report presents preliminary case studies on buildings that had been rehabilitated to conform to the L.A. hazard reduction ordinance. It was found that both rehabilitated and non-strengthened buildings suffered damage due to separation of the outer wythe of brick, out-of-plane bending failure, and/or in-plane shear failures of wall piers, especially at building corners.

The work in progress concerning aseismic earthen housing in China / Yaoxian, Ye / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of new mexico, albuquerque, may 24-28, 1981* / Washington: National science foundation, 1981, p. 509-534

Theme:

Language: English

Abstract: ICCROM

Damage on adobe buildings in china. Aseismic design and mechanical characteristics of earthen materials. Full scale housing described. Wooden frames suggested. Small windows.

The work on earth structures in the Dominican Republic: past and present / Luther, David S. / In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of new mexico, albuquerque, may 24-28, 1981* / Washington: National science foundation, 1981, p. 235-250

Theme:

Language: English

Abstract: ICCROM

Introduction to the history of earthen buildings in the dominican republic and description of experiments carried out with adobe and rammed earth techniques, soil stabilisation, forms, roof structures, preservation methods, and, the future trends of earth construction in this country.

Traditional earthen architecture in Uzbekistan – evaluation of earthquake resistance and strategie for improvement / Schroeder, Schwarz, Tulaganov / In: Preprints of the 9th International Conference on the Study and Conservation of earthen Architecture, 29 November – 2 December 2003, Yazd, Iran

Theme:

Language:

Abstract:

Traité de construction en terre / Houben, Hugo; Guillaud, Hubert / CRATerre , Marseille: Editions Parenthèses, 1989

Theme:

Language:

Abstract: ICCROM

This book presents a synthesis of the knowledge of earthen construction, a result of the theoretical and practical works carried out since 1973 by the group CRATerre. It is intended as a practical manual and includes: earth material, identification of the soils, stabilization, tests and characteristics, types of use, construction techniques, elements of conception, constructions against disasters, surface revestments and protection.

Turkish standards and codes on adobe and adobe construction / Yorulmaz, Mufit /, In: *Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of new mexico, albuquerque, may 24-28, 1981* / Washington: National science foundation, 1981, p. 503-519

Theme:

Language: English

Abstract: ICCROM

Standards on adobe, stabilized and not, and on construction methods are presented for turkey and compared with other codes. 13 references.

UNESCO-ICHO 2nd joint mission to Bam and its citadel / 11-19 March 2004

Theme:

Language:

Abstract: